CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING
ENGINEERING AND CONSTRUCTION DIVISION

GEOTECHNICAL STUDY
WILLOW WATERHOLE DRAINAGE AND PAVING
WILLOW WATERHOLE AREA

WBS NO. M-001013-0001-3
CITY OF HOUSTON, TEXAS

PROJECT NO. 11-609E

TO

EDMINSTER HINSHAW RUSS AND ASSOCIATES
HOUSTON, TEXAS

BY

GEOTECH ENGINEERING AND TESTING

SERVICING

TEXAS, LOUISIANA, NEW MEXICO, OKLAHOMA

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Edminster, Hinshaw, Russ and Associates, Inc.
10555 Westoffice Drive
Houston, Texas 77042

Project No.: 11-609E
Report No: 1
Project Type: 24/33/35
May 14, 2014

Attention: Mr. Jerry P. Preston, P.E., CFM
Department Manager

GEOTECHNICAL STUDY
WILLOW WATERHOLE DRAINAGE AND PAVING
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Gentlemen:

Submitted here is Geotech Engineering and Testing (GET) geotechnical report on the study of subsurface conditions for the above referenced project. This study was conducted in general accordance with our Proposal No. P13-116, Revision VI, dated December 3, 2013. Authorization to proceed for this study was received through a Professional Services Contract between Edminster, Hinshaw, Russ and Associates, Inc. and GET and signed by Mr. Edward G. Gamel, P.E. Vice President of EHRA on December 13, 2013.

This report presents the results of our field exploration and laboratory testing together with design recommendations for the proposed paving and drainage improvements for the subject project.

We appreciate the opportunity to be of service. Should you have any questions or need additional assistance, please call.

Very truly yours,

GEOTECH ENGINEERING AND TESTING
TEXAS BOARD OF PROFESSIONAL ENGINEERS
REGISTRATION NUMBER F-001183

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1.0 EXECUTIVE SUMMARY

It is planned to make drainage and paving improvements to Willow Waterhole Area in City of Houston, Texas. We understand that the existing asphalt and concrete paving will be removed and replaced with new concrete paving. In addition, underground utilities will be installed along the proposed project alignments. The invert depths for the storm and sanitary sewers will be less than 23-ft below the existing grade.

Furnished information indicates that open-trench method of construction will be used for underground utility installations. We understand that waterlines may be adjusted along the project alignments. This study was conducted is general accordance with the City of Houston, Department of Public Works & Engineering, Infrastructure Design Manual, dated July 2012. This report contains a description of our field and laboratory testing results together with engineering analysis and recommendations for the construction of the proposed facilities along the project alignments.

The soil conditions were explored by conducting seven (7) borings (B-1 through B-7) for paving and underground utilities. The soil borings were drilled along the project alignments to depths ranging from 20- to 33-ft below the existing grade. The soil stratigraphy for the project alignment is summarized as follows:

1. In general, based on our field exploration and laboratory test data, the soils along the project alignment appear to be uniform. The soils stratigraphy along the project alignment is summarized as follows:

Stratum No.	Range of Depth, ft.	Soil Description
		EXISTING ASPHALT PAVEMENT (1.5” to 2.5” in Thickness
		EXISTING CONCRETE PAVEMENT (5.0” to 7.5” in Thickness)
I	0.5 – 8	FILL: FAT CLAY, soft to very stiff, dark brown, gray, dark gray, light gray, with root fibers to 6’, ferrous and calcareous nodules (CH)
II	2 – 33	FAT CLAY, soft to very stiff, dark brown, light gray, light brown, gray, reddish brown, with root fibers to 4’, ferrous and calcareous nodules (CH)
III	10 – 18	LEAN CLAY WITH SAND, soft to firm, light gray, dark gray, with ferrous nodules (CL), In Boring B-3 only
IV	12 – 24	SANDY SILT, medium dense, light brown, brown, gray (ML); In Borings B-2 and B-5 only
V	18 – 26	SILTY SAND, medium dense, reddish brown (SM); In Boring B-3 only

2. Depth to groundwater water will be important for design and construction of the proposed facilities. Our short-term field exploration along the alignments indicated that groundwater was encountered at depths ranging from 17- to 24-ft below the existing grade. Groundwater rose to depths ranging from 16- to 24-ft below the existing grade 24 hours after drilling.

3. We understand that open cut excavation method of construction will be used for the underground utilities installations. The bedding and backfill recommendations for the construction of the proposed underground utilities are also presented in this report.

4. We understand that the proposed paving for the Willow Waterhole area will consist of concrete pavement. Furthermore, we understand traffic loading will be residential streets and major thoroughfare. The concrete pavement was designed on the basis of "1993 AASHTO Guide for Design of Pavement Structures." Based on the assumed traffic conditions, the recommended concrete pavement thickness is as follows:

Major thoroughfare		
Design, ESAL × 10^6	Concrete Pavement Thickness, inch(es)	Subgrade Lime Stabilization Thickness, inch(es)
10.0	10.0	8.0

Type	Residential Streets	
	Concrete Pavement Thickness, inch(es)	Subgrade Lime Stabilization Thickness, inch(es)
Curb to Curb Width Less Than or Equal to 27'	6.0	6.0
Curb to Curb Width Greater Than 27'	7.0	6.0

5. Subgrade preparation in pavement areas should specify compaction of the upper six-inch to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content. Depending on the major type of soils encountered along the project alignment, lime stabilization of the subgrade soils should most likely be performed. The subgrade soils should be stabilized, using lime based on the City of Houston Specifications, Section 02336. Use 7% lime by dry weight to stabilize the subgrade soils. This results in application rates of 27 and 36 pounds of lime, per square yard per six-inch and eight-inch of compacted thickness, respectively. City of Houston Specifications, Section 02336, can be used as procedural guides for placing, mixing and compacting the lime stabilizer and the soils.

6. We understand that storm/sanitary sewers are planned for this project. The maximum depth of the storm/sanitary sewers will be less than 23-ft. The design recommendations for the storm/sanitary sewers are presented in this report.

2.0 INTRODUCTION

It is planned to make drainage and paving improvements to Willow Waterhole Area in City of Houston, Texas. A site vicinity map of the project alignment is presented on Plate 1. We understand that the existing concrete and asphalt paving will be removed and replaced with concrete paving. In addition, underground utilities will be constructed along the project alignment. The specific project information is as follows:

Facility	Remarks
Storm Sewers	The invert depth will be about 1.5- to 23-ft along most of the alignment. Storm sewer depth will be about 23-ft at the intersection of Greenwillow and Braeswood. The length of storm sewer will be about 6,000-ft. A large portion of the storm sewer will consist of boxes ranging in size from 4' x 2' to 12' x 8'. Total box length will be about 3,800-ft. The construction technique will be open excavation.
Sanitary	The invert depth will range from 3- to 9-ft. The alignment length will be about 5,417-ft. The construction technique will be open excavation. The sanitary sewer pipe diameters will be 8-inches, 10-inches and 12-inches.
Waterlines	We understand that adjustment to existing waterlines may be required along the portions of the project alignments. The construction technique will be open excavation.
Paving	The pavement improvements will cover about 24,500-sq.ft and will consist of concrete paving. The traffic loading will be based on residential and major thoroughfare traffic.

Furnished information indicates that open-trench method of construction will be used for underground utility installations. This report contains a description of our field and laboratory testing programs together with engineering analysis and recommendations for the proposed improvements. The pavement design in this study is in general accordance with ASSHTO 1993 Guide of Design of Pavement Structure (Ref. 1). Furthermore, this report provides recommendation for construction of the underground utilities along the project alignment. Our recommendations on underground utilities, site preparation and soil stabilization are in general accordance with the City of Houston, Department of Public Works & Engineering, Infrastructure Design Manual, dated July 2012 (Ref. 2). The scope of work (number of borings and depths) for this project was specified by EHRA.

3.0 FIELD EXPLORATION

3.1 Pavement Coring

The existing pavement was cored prior to drilling and sampling the soil borings. The results of pavement coring show that the existing pavement consists of asphalt and concrete pavement. The existing pavement thicknesses are presented on Plate 2 and on the respective boring logs. The pavement core locations were patched with cold patch asphalt or ready mix grout.

3.2 Drilling and Sampling

At the request of the City of Houston, the soil conditions were explored by conducting seven (7) soil borings (B-1 through B-7) along the project alignments. The soil boring locations were discussed with Mr. Jerry P. Preston, P.E. prior to drilling. A summary of the borings coordinates, elevations and station number information are presented on Plate 3.

During drilling operation, we encountered underground obstruction and auger refusal at about 7-ft at boring B-4 location. Drilling operation was shut down and Mr. Sam Samoo, Engineer for the project, called immediately Mr. Hasnain Jaffari, P.E. with City of Houston and provided updates and discussed drilling situation. Boring B-4 location was staked based on Texas 811 information and all available resources provided on HOUSTON GIMS (online source to locate the public utilities in Houston Area- both in use and abandoned) to avoid encountering any underground utilities or obstructions. But, still we encountered some unforeseen condition at this location. Therefore, we had to offset boring location B-4 and re-drill this boring.

The borings were drilled along the project alignments ranging from 20 to 33-ft below the existing grade and the soil sampling was done continuously to 20-ft and at 5-ft intervals thereafter to the completion depths of the borings. Approximate boring locations are presented in Appendix A.

The cohesive soils were sampled in general accordance with the ASTM D 1587. Cohesionless soils were generally sampled with a split-spoon sampler driven in general accordance with the Standard Penetration Test (SPT), ASTM D 1586. This test is conducted by recording the number of blows required for a 140-pound weight falling 30-inches to drive the sampler 12-inches into the soil. Driving resistance for the SPT, expressed as blows per foot of sampler resistance (N), is tabulated on the boring logs.

Soil samples were examined and classified in the field, and cohesive soil strengths were estimated using a calibrated hand penetrometer. This data, together with a classification of the soils encountered and strata limits, is presented on the soil stratigraphy profile presented in Appendix A. The logs of borings and key to the log terms and symbols are also presented in Appendix A.

Depth to groundwater is important for design and construction of the proposed facilities. For this reason, borings were drilled dry. Water level observations made during drilling and shortly after drilling are indicated at the bottom portion of each individual boring log. The boreholes were grouted using tremie method after the completion of the field work.

4.0 LABORATORY TESTS

4.1 General

Soil classifications and shear strengths were further evaluated by laboratory tests on representative samples of the major strata. The laboratory tests were performed in general accordance with ASTM Standards. Specifically, ASTM D 2487 is used for classification of soils for engineering purposes. Furthermore, summary of test results are presented in Appendix A.

4.2 Classification Tests

As an aid to visual soil classifications, physical properties of the soils were evaluated by classification tests. The tests were conducted in general accordance with ASTM standards. These tests consisted of natural moisture content tests (ASTM D 4643), percent finer than the No. 200 sieve tests (ASTM D 1140) and Atterberg limit determinations (ASTM D 4318, Method A). Similarity of these properties is indicative of uniform strength and compressibility characteristics for soils of essentially the same geological origin. Results of these tests are tabulated on the boring logs at respective sample depths.

4.3 Strength Tests

Undrained shear strengths of the cohesive soils, measured in the field, were verified by calibrated hand penetrometer tests, unconfined compressive strength tests (ASTM D 2166) and torvane tests. Natural water content and dry unit weight were determined routinely for each unconfined compressive strength test. These test results are also presented on the boring logs.

4.4 Particle Size Analysis Test

This test was conducted in general accordance with ASTM D 422, the Standard Method for Particle-Size Analysis of Soils. This test was performed on selected sample obtained from Borings B-2, B-3 and B-4 at depths of 14- to 16-ft, 10- to 12-ft and 28- to 30-ft, respectively. The analysis results are presented on Plates 4 through 6.

4.5 Soil Sample Storage

Soil samples tested or not tested in the laboratory will be stored for a period of fourteen days subsequent to submittal of this report. The samples will be discarded after this period, unless we are instructed otherwise in writing

5.0 SITE GEOLOGY

According to the soil survey of Harris County, Texas (prepared by the U.S. Department of Agriculture Soil and Conservation Service (1976), geologically the project areas at the proposed alignment lies on the Lakes Charles-Urban Land Complex (Lu) and Verland-Urban Land Complex (Mu). The geologic character of each soil type is described below:

Lake Charles-Urban Land Complex (Lu) – This is a nearly level complex in broad, irregular areas that range from 20 acres to about 1,800 acres in size. Slopes are mainly 0 to 1 percent, but range from 0 to 3 percent in some areas leading to drainage ways. Lake Charles soils make up 20 to 85 percent of this unit; Urban land, 10 to 75 percent; and other soils, 15 percent or less. The areas making up this complex are so intricately mixed that separation was not feasible at the scale used in mapping.

The surface layer of the Lake Charles soil is about 36 inches thick. In the upper 22 inches it is very firm, neutral, black clay. In the lower 14 inches it is very firm, mildly alkaline, very dark gray clay. In the layer below that it is about 16 inches thick and is very firm, mildly alkaline, dark gray clay that has intersecting slickensides. The next layer, to a depth of 74 inches, is very firm, mildly alkaline, gray clay that has mottles of olive brown and yellowish brown.

Urban land consists of soils that have been altered or covered by buildings or other urban structures. Classifying these soils is not practical. Typical structures are single- and multiple-unit dwellings, streets, schools, churches, parking lots, office buildings, and shopping centers that are less than 40 acres in size. The Urban land includes remnants of Lake Charles soils that have been altered by cutting, filling, and grading in urban development. In many areas of this mapping unit 6 to 18 inches of fill material covers the natural soil. Included with this complex in mapping are small areas of Beaumont, Bernard, Midland, and Vamont soils. This mapping unit has severe limitations for urban development. The main limitation is the high shrink-swell potential of the clay, which results in buckled streets and sidewalks and cracked walls. Lawns and gardens are difficult to establish because of the high clay content of the soils.

Verland-Urban land complex (Mu) – The soils in this mapping unit are nearly level and are in broad, irregular areas that range in size from about 30 to 600 acres. Slopes range from 0 to 1 percent, but the average is 0.5 percent. Most areas are open prairie, but some are covered with native harwood tress.

These soils make up 20 to 75 percent of this complex, Urban land, 10 to75 percent, and other soils, 15 percent or less. The surface layer is firm, strongly acid dark grayish brown silty clay loam about 7 inches thick. The next layer, extending to a depth of 50 inches, is very firm, dark gray clay that is slightly acid in the upper part and neutral in the lower part. It has slickensides in the upper part. The next layer, to a depth of 72 inches, consists of very firm, moderately alkaline clay that us mottled gray, olive yellow, and brownish yellow.

Included in mapping are small areas of Bernard, Lake Charles, Beaumont, Ozan, and Gessner soils. This mapping unit has severe limitations for urban development. Poor drainage and shrinking and swelling in the underlying layers are the main limitations.

6.0 GENERAL SOILS AND DESIGN CONDITIONS

6.1 Site Conditions

The project alignment generally consists of asphalt and concrete paved roadway. In general commercial and residential structures exist in the vicinity of the project alignment. Project site pictures were taken during our site visit and drilling operation. These pictures are presented in Appendix B.

6.2 General Soil Stratigraphy

Field and laboratory test data indicate that soil stratigraphy along the project alignments are relatively variable. **Details of subsoil conditions at each boring location are presented on the respective boring logs, provided in Appendix A**. In general, the soils can be grouped into five (5) major strata with depth limits and characteristics as follows:

Stratum No.	Range of Depth, ft.	Soil Description*
		EXISTING ASPHALT PAVEMENT (1.5” to 2.5” in Thickness
		EXISTING CONCRETE PAVEMENT (5.0” to 7.5” in Thickness)
I	0.5 – 8	FILL: FAT CLAY, soft to very stiff, dark brown, gray, dark gray, light gray, with root fibers to 6’, ferrous and calcareous nodules (CH)
II	2 – 33	FAT CLAY, soft to very stiff, dark brown, light gray, light brown, gray, reddish brown, with root fibers to 4’, ferrous and calcareous nodules (CH)
III	10 – 18	LEAN CLAY WITH SAND, soft to firm, light gray, dark gray, with ferrous nodules (CL), In boring B-3 only
IV	12 – 24	SANDY SILT, medium dense, light brown, brown, gray (ML); In borings B-2 and B-5 only
V	18 – 26	SILTY SAND, medium dense, reddish brown (SM); In boring B-3 only

* Classification in general accordance with the Unified Soil Classification System (ASTM D 2487)

6.3 Soil Properties

Soil strength and index properties and how they relate to the pavement design and underground utility installations along the project alignment are summarized below:

Stratum No.	Soil Type	PI(s)	SPT	Soil Expansivity	Soil Strength, tsf	Remarks
I	Fill: Fat Clay (CH)	37 – 55	–	Expansive to Highly Expansive	0.23 – 1.90	–
II	Fat Clay (CH)	39 – 55	–	Expansive to Highly Expansive	0.23 – 1.51	–
III	Lean Clay with Sand (CL)	26	–	Moderately Expansive	0.23 – 0.40	–
IV	Sandy Silt (ML	–	17 – 28	Non-Expansive	–	Moisture Sensitive
V	Silty Sand (SM)	–	23 – 24	Non-Expansive	–	Moisture Sensitive

Legend: PI = Plasticity Index
SPT = Standard Penetration Test

6.4 Water-Level Measurements

The soil borings were first drilled dry to evaluate the presence of perched or free-water conditions. The levels where free water was first encountered in the open boreholes during drilling and 24 hours after drilling are shown on the boring logs. Our groundwater water measurements are as follows:

Boring No.	Groundwater Depth, ft. at the Time of Drilling	Groundwater Depth, ft. at 24-Hour Later
B-1	18	18
B-2	DRY	DRY
B-3	17	16
B-4	24	24
B-5	17	16
B-6 and B-7	Dry	Dry

Fluctuations in groundwater generally occur as a function of seasonal moisture variation, temperature, groundwater withdrawal and future construction activities that may alter the surface drainage and subdrainage characteristics of this site.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeable silts/sands requires long term observation of monitoring wells and/or piezometers. It is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration. The installation of piezometers/monitoring wells was beyond the scope of our study. We recommend that the groundwater level be verified just before construction if any excavations such as construction of underground utilities, etc. are planned.

We recommend that GET be immediately notified if a noticeable change in groundwater water occurs from that mentioned in our report. We would be pleased to evaluate the effect of any groundwater changes on our design and construction sections of this report.

7.0 UNDERGROUND UTILITIES

7.1 General

We understand that underground utility installations will include storm sewers and sanitary sewers. Furnished information indicated that the maximum depth of these utilities will be less than 23-ft. Furthermore, adjustments to the existing waterlines are needed at five (5) street intersections within the project area. We further understand that Open-trench method will be used for the underground utility installations. Soil Borings B-1 through B-7 were drilled along the project alignment for the underground utilities and paving to depths of 20 to 33-ft below the existing grade. We understand that the proposed underground utilities will be constructed according to the "City of Houston Specifications, Section 02317 – Excavation and Backfill for Utilities, and Section 02447 – Augering Pipe and Conduit".

7.2 Open-Trench Method

7.2.1 Sewer lines and Storm Sewers

In general, where dry stable trench conditions exist, bedding and backfill for the sanitary sewer lines and storm sewers should be in accordance with the City of Houston Specifications Drawing No. 02317-03. Bedding for the sanitary sewerlines and storm sewers, where wet stable trench conditions exist (where excavations below groundwater table are required), should be in accordance with the City of Houston Specifications Drawing No. 02317-02.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as silty sand (SM), sandy silt (ML) and soft clay soils, exist at various depths in some of the borings along the project alignment. A summary of the unsatisfactory soils, locations and depths are as follows:

Boring(s)	Depth Range, ft.	Approximate Utility Invert Depth (ft)	Soil Description
B-2	14 to 24	11.5 to 13.0	Sandy Silt (ML)
B-3	0 to 2, 8 to 10, 12 to 18 and 18 to 26	15.0 to 17.0	Soft Clays (CH and CL), Silty Sand (SM)
B-5	12 to 20	10.5	Sandy Silt (ML)
B-6	4 to 6	9.0	Soft Fat Clay (CH)

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented in accordance with the "City of Houston Standard Specifications, Section 01578 – Control of Groundwater and Surface Water". Furthermore, the contractor may have to over excavate an additional 6-inch and remove unstable or unsuitable materials with approval by geotechnical engineer, and then place an equal depth of cement stabilization sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct our borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Sand backfill used in the cement-stabilized sand and sand backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 4 for the cement-stabilized sand and less than 7 for the sand backfill section, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to the "City of Houston Standard Specifications, Section 02321 – Cement Stabilized Sand".

7.2.2 Waterlines

The bedding and backfill for the proposed waterlines or waterline adjustments should be constructed in accordance with the City of Houston Specifications drawing No. 02317-04 for open-trench construction. Trenches for the proposed waterlines must have a width below the top of the pipe of not less than the outside diameter of the pipe plus 24-inches and shall be wide enough to permit making up the joints but shall not be wider than the outside diameter of the pipe plus 36-inches.

In general, 12-inch of bank sand should be placed above the waterlines. Twelve-inch lifts of bank sand should be placed below the waterlines for dry excavation bottom. In case of wet excavation bottom, geotextile fabrics should be placed at the excavation bottom and along the excavation sides to a height of at least 24 inches.

8.0 BOX CULVERTS AND JUNCTION BOXES

8.1 General

We understand that box culverts and junction boxes will be installed along a portion of the proposed project alignment. Excavation and groundwater control for construction of the box culverts and junction boxes should be in accordance with our recommendations provided in construction consideration section of this report.

8.2 Allowable Bearing Pressure

We understand that box culverts ranging in size from 4' x 2' to 12' x 8' will be installed along a portion of the project alignment. Furthermore, junction boxes with invert depth of 11.5 to 23-ft will be installed along the project alignment. The proposed box culverts may be designed in accordance with the parameters presented on Plate 7. The allowable bearing pressures for support of the box culverts and junction boxes are as follows:

Boring No.	Foundation Type	Approximate Invert Depth, ft.(1)	Allowable Net Bearing Pressure, psf	
			Dead Load(2)	Total Load (Dead + Live)
B-1	Junction Box	12.5	2,000	2,500
B-1	Box Culvert	11.0	2,000	2,500
B-2	Junction Box	13.0	2,000	2,500
B-2	Box Culvert	11.5	2,000	2,500
B-3	Junction Box	17.0	1,000	1,250
B-3	Box Culvert	15.0	1,000	1,250
B-4	Junction Box	23.0	2,500	3,750
B-4	Box Culvert	21.0	2,500	3,750
B-5	Junction Box	11.5	2,000	2,500
B-5	Box Culvert	10.0	2,000	2,500
B-6	Box Culvert	9.0	2,000	2,500

1. Below existing grade
2. Dead load + sustained live load

Footings proportioned in accordance with the above bearing capacity values will have a safety factor of 2.5 and 2.0 with respect to shearing failure for dead and total loading, respectively.

8.3 Bedding and Backfilling

The proposed concrete box culverts and junction boxes should be placed on a well prepared, properly compacted working surface. Cast-in-place culverts and junction boxes can be supported on the natural soils provided subgrade is protected from construction disturbances and surface water is not allowed to pond within the excavation. If any soft or unstable soils are encountered in the proposed box culvert area, these soils should be removed to level of firm and stable soils and replaced with structural fill in accordance with site preparation section of this report. We recommend the exposed subgrade be uniformly proofrolled and compacted to at least 95 percent of Standard Proctor (ASTM D 698) maximum dry density at a moisture content between optimum and +3% of optimum. The excavation, trenching, foundation, embedment, and backfilling for the proposed box culverts and junction boxes shall be in accordance with City of Houston, Department of Public Works & Engineering, and Infrastructure Design Manual, dated July 2012 (Ref. 2).

A seal slab may be needed if saturated and unstable subgrade soils are encountered at the bottom of culverts and junction boxes in order to provide a working platform.

Sand used in the cement-stabilized sand backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 4 for the cement-stabilized sand, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to City of Houston (COH) Department of Public Works & Engineering, dated July 2012 (Ref. 2).

8.4 Buoyancy

The proposed box culverts and junction boxes may experience uplift loads from the groundwater during flood conditions. The box culverts should perform satisfactorily if a design factor of safety against uplift loads of 2.0 is used. In general, the hydrostatic pressure will be resisted by the dead weight of the structure, weight of the overburden soils above the top of the box culverts or junction boxes and the friction or adhesion between the walls and natural soils or fill. A submerged unit weight of 60 pounds per cubic foot (pcf) and 85 pcf can be used for soils and concrete, respectively, to compute the resistance to uplift loads. An adhesion value of 200 psf can be used between the backfill and the box culverts or junction boxes to resist the uplift loads. A factor of safety of 2.0 is included in the adhesion value.

9.0 PAVEMENT RECOMMENDATIONS

9.1 General

It is planned to reconstruct approximately 8,070-ft ± linear feet of paving in Willow Waterhole Area in City of Houston, Texas. We understand traffic loading will consist of residential and major thoroughfare. We understand that the existing asphalt and concrete pavement will be removed and replaced with new concrete paving. The new pavement design is in accordance with the "1993 ASSHTO Guide for Design of Pavement Structures" (Ref. 1). Furthermore, our recommendations on site preparation and soil stabilization are in general accordance with the City of Houston (COH) Department of Public Works & Engineering, Dated July 2012 (Ref. 2).

9.2 Traffic Information

Based on the information provided by the client, GET estimated the traffic volume and 18-kip equivalent axle loads (EALs). Furthermore, the pavement will be designed based on residential streets and major thoroughfare traffic. A design ESAL of 10×10^6 was used for the proposed major thoroughfare. The results of the pavement design analyses for major thoroughfare traffic are provided in the following sections.

9.3 Subgrade Stabilization

The type of subgrade stabilization for the concrete pavement areas will depend on the final grade elevation. Subgrade preparation in pavement areas should specify compaction of the upper six-inch to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content. Depending on the type of soils encountered along the project alignment, lime stabilization of the subgrade soils should most likely be performed. The subgrade soils should be stabilized, using lime based on the City of Houston Specifications, Section 02336. Use 7% lime by dry weight to stabilize the subgrade soils. This results in application rates of 27 and 36 pounds of lime, per square yard per six-inch and eight-inch of compacted thickness, respectively. City of Houston Specifications, Section 02336, can be used as procedural guides for placing, mixing and compacting the lime stabilizer and the soils.

9.4 Recommended Subgrade Design Values

Results of the soils test indicated that subgrade soils consist of fat clay fill (CH) soils based on Unified Soils Classification System (ASTM D 2487). The recommended CBR and M_R values for fat clay fill (CH) subgrade soils are estimated to be 5 and 7,500 psi, respectively.

9.5 Concrete Pavement

9.5.1 Major thoroughfare (Braeswood Blvd.)

The following design parameters (based on 1993 AASHTO Guide for Design of Pavement Structures, Ref. 1) were used in the concrete pavement design for the proposed project alignment.

AASHTO Design Parameter	Pavement Design Value
ESAL × 10^6 for 20-year design life	10.0
Reliability, R	95%
Overall Standard Deviation, S_0	0.35
Load Transfer Coefficient, J	3.2
Loss of Support, LS	1.0
Drainage Coefficient, C_d	1.2
Design Serviceability Loss, Δ psi	2.0
Concrete Modules of Rupture (28 days) in psi, S_c’	600
Concrete Compressive Strength at 28 days in psi, f_c’	3,500
Effective Modulus of Subgrade Reaction k, in pci	130

Based on the above design parameters, the minimum concrete pavement section thickness are as follows:

Design, ESAL × 10^6	Concrete Pavement Thickness, inch(es)	Subgrade Stabilization Thickness, inch(es)
10.0	10.0	8.0

Detailed design computations are presented in Appendix C. Our design recommendations also consider excellent drainage is provided near the pavement structures, assuming the pavement are exposed to moisture levels approaching saturation from 1 to 5 percent of the time. Concrete should meet the requirements of the City of Houston design paving specifications as well as AASHTO “Guide Specifications for Highway Construction and the Structural Specifications for Transportation Materials.” The construction of rigid pavement should be in accordance with the City of Houston Standard Specification Drawing No. 02751-01.

Subgrade preparation in pavement areas should specify compaction of the upper eight-inch to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content. Depending on the major type of soils encountered along the project alignment, lime stabilization of the subgrade soils should most likely be performed. The subgrade soils should be stabilized, using lime based on the City of Houston Specifications, Section 02336. Use 7% lime by dry weight to stabilize the subgrade soils. This results in application rate of 36 pounds of lime, per square yard per eight-inch of compacted thickness. City of Houston Specifications, Section 02336, can be used as procedural guides for placing, mixing and compacting the lime stabilizer and the soils.

The steel reinforcement was designed using No. 4 and No. 5 bars as described below:

- The reinforcing steel was designed on the basis of Grade 60 steel. The longitudinal steel reinforcement should be No. 4 bars at 12.5-inch spacing. The transverse steel reinforcement should be No. 4 bars at the spacing of 36-inch for a pavement width of 25-ft. We recommend a lap length of 22-inches for the No. 4 bars. The end bar spacing should be 3.5 inches.

- The reinforcing steel was designed on the basis of Grade 60 steel. The longitudinal steel reinforcement should be No. 5 bars at 18.25-inch spacing. The transverse steel reinforcement should be No. 5 bars at the spacing of 36-inch for a pavement width of 25-ft. We recommend a lap length of 27-inches for the No. 5 bars. The end bar spacing should be 4-inches.

9.5.2 Residential Streets

The minimum concrete pavement section thicknesses are as follows:

	Curb to Curb Width Less Than or Equal to 27’	Curb to Curb Width Greater Than to 27’
Surface: Concrete Pavement	6	7
Subgrade: Lime-Stabilized Subgrade Soils, Compact to 95% of Standard Density (ASTM D 698) at a moisture content between optimum and +3% of optimum.	6	6

Notes:

1. Reinforcing for residential streets shall meet the size and spacing shown in the following table:

PAVEMENT THICKNESS D (IN)	PAVEMENT WIDTH (FT)	LONGITUDINAL STEEL #4 BARS			TRANSVERSE STEEL #4 BARS
		NUMBER OF BARS	SPACING (IN)	END BAR SPACING (IN)	SPACING (IN)
6	28	17	20.50	4	36
7	25	17	18.25	4	36
7	35	24	18.00	3	36

2. The concrete should have a minimum flexural strength of 500 psi at 7 days and 600 psi at 28 days, using the ASTM method C78. This corresponds to an approximately compressive strength of 3500 psi at 28 days, using the ASTM method C39. Steel used as reinforcement should be Grade 60.

3. Subgrade preparation in pavement areas should specify compaction of the upper six-inch to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content. Depending on the major type of soils encountered along the project alignment, lime stabilization of the subgrade soils should most likely be performed. The subgrade soils should be stabilized, using lime based on the City of Houston Specifications, Section 02336. Use 7% lime by dry weight to stabilize the subgrade soils. This results in application rate of 27 pounds of lime, per square yard per six-inch of compacted thickness. City of Houston Specifications, Section 02336, can be used as procedural guides for placing, mixing and compacting the lime stabilizer and the soils.

4. Sand fill in pavement areas should only be used for leveling purposes. The sand thickness should be limited to a maximum of two-inches.

10.0 CONSTRUCTION CONSIDERATIONS

10.1 Groundwater Control

10.1.1 General

We understand that the depths of underground utilities will be less than 23-ft below existing grade. Our short-term field exploration along the alignments indicated that groundwater was encountered at depths ranging from 17- to 24-ft below the existing grade. Groundwater rose to depths ranging from 16- to 24-ft below the existing grade 24 hours after drilling completion. Hence, groundwater dewatering may be required. Fluctuations in groundwater can occur as a function of seasonal moisture variation. Groundwater control recommendations are presented in the following report sections.

10.1.2 Dewatering Technique

The water level readings measured in Borings B-1 through B-7 indicate that the range of stabilized groundwater level is approximately between 16- to 24-ft. Therefore, groundwater dewatering may be required. **Dewatering is very important on this project in order to prevent potential bottom blow up in the sands.** In the event that groundwater is encountered during construction, it is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or a trench sump-pump immediately. Wellpoint system can be used in the area where sands are present.

Design of a wellpoint system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of dewatering system for groundwater and surface water control should be in accordance with the City of Houston Specifications, Section 01578 − Control of Ground Water and Surface Water.

10.2 OSHA Soil Classifications

The subsoils can be classified in accordance with Occupational Safety and Health Administration (OSHA) Standards, dated October 31, 1989 of the Federal Register. OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. The description of four (4) types in classification system is summarized in the Appendix D.

Based on our geotechnical exploration and laboratory test results, details of soil classifications at each boring are summarized in the OSHA Soil Classification, presented in Appendix D. Furthermore, a letter for trench safety recommendation is provided separately.

10.3 Excavations

Each side of an excavation or trench which is five-ft or deeper must be protected by sheeting/bracing shoring or sloped. Based on soil strength data and OSHA soil classifications, temporary (less than 24 hours) open-trenched, non-surcharged, and unsupported excavations should be made on slopes of about 1.5(h):1(v). Vertical cuts can be constructed, provided shoring and bracing are used for the excavation wall stability. Benched excavation can also be used with average slopes of about 1(h):1(v) and steps should not be higher than five-ft. In all cases, excavations should conform to OSHA guidelines. Flatter slopes may have to be used if large amounts of sand need to be excavated for deep installations. Specifications should require that no water be allowed to pond in the excavations. The surface slopes should be protected from deterioration and weathering if they are to be left open for more than 24 hours.

Excavations should be performed with equipment capable of providing a relatively clean bearing area. Excavation equipment should not disturb the soil beneath the design excavation bottom and should not leave large amounts of loose soil in the excavation.

10.4 Lateral Earth Pressures

In the event that open excavations are not used, the proposed underground utilities can be installed using trench sheeting. The sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate 8. The trenching and shoring operations should follow OSHA Standards. We recommend a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety.

10.5 Site Preparation

Site preparation should be conducted in accordance with the “City of Houston Standard Specifications, Section 02221 – Removing Existing Pavements and Structures and Section 02233 – Clearing and Grubbing”. In general, subgrade preparation should be as follows:

1. The requirement for removal of any existing paving, and subsoil materials will depend on final grades and other alignment information. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trunks under the pavement should be removed to a root size of less than 0.5-inches. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. The subgrade areas should then be proofrolled with a loaded dump truck or similar pneumatic-tired equipment with loads ranging from 25- to 50-tons. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. The proofrolling should be conducted in accordance with TxDOT Standard Specification Item 216. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. Any subgrade stabilization should be conducted after site proofrolling is completed and approved by the geotechnical engineer. The proofrolling operations should be observed by an experienced geotechnician.

3. Off-site borrow for fill should consist of lean clays with a liquid limit not exceeding 40 and a PI between 12 and 20. These soils should be placed in loose lifts not exceeding eight-inches and compacted to at least 95% of maximum standard Proctor density (ASTM D 698) at moisture contents between optimum and +3% of optimum. Bank sands should not be used as select structural fill. On-site soils, free of organics, (with the exception of sands and silts) are also suitable for use as structural fill.

4. In cut areas, the soil should be excavated to grade and the surficial soil proofrolled and scarified to a minimum depth of six-inches and recompacted to the previously mentioned density and moisture content.

5. Positive site drainage should be developed at the beginning of the project to limit construction difficulties with wet surface soils.

10.6 Suitability of On-Site Soils for Use as Fill

10.6.1 General

Fill requirements should be in accordance with the 'City of Houston Standard Specifications, Section 02316 –Excavation and Backfill for Structures, Section 02317 – Excavation and Backfill for Utilities and Section 02320 – Utility Backfill Materials". The on-site soils can be used as fill materials as described in the following report sections.

10.6.2 Select Backfill

This is the type of fill that can be used for the structures or utilities. These soils should consist of lean clays with plasticity indices between 8 and 20 and amount of passing No. 200 sieve greater than 50 percent.

10.6.3 Random Backfill

This type of fill does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. They can be used for the structures or utilities after treatment.

10.6.4 General Fill

This type of fill consists of silts, sands and clays. However, the silts and sands are moisture sensitive and are difficult to compact in a wet condition (they may pump). Furthermore, these soils can erode easily. Their use is not recommended as backfill materials. They can be used for site grading and in unimproved areas.

10.6.5 On-Site Fill Soil Classification

Based on Borings B-1through B-7, the on-site soils can be used as fill materials as described below:

		Use as Fill			
Stratum No.[1]	Soil Type	Select Backfill	Random Backfill	General Fill	Notes
I	Fill: Fat Clay (CH)	–	–	✓	2, 3
II	Fat Clay (CH)	–	✓	✓	2, 3
III	Lean Clay with Sand (CL)	–	✓	✓	2, 4
IV	Sandy Silt (ML)	–	–	✓	2, 5
V	Silty Sand (SM)	–	–	✓	2, 5

Notes:

1. See soil stratigraphy and design conditions sections of this report for strata description.
2. All fill soils should be free of organics, roots, etc.
3. These soils, once lime modified (7% by dry weight), can be used as select structural fill.
4. Soils with PI greater than 20 should be lime modified with 4% by dry weight and can be used as select structural fill.
5. The on-site cohesionless soils are moisture sensitive and erode easily. These soils will pump when they get wet. Compaction difficulties will occur in these soils in a wet condition.

10.7 Site Drainage

It is recommended that site drainage be well developed. Surface water should be directed away from the structure (use a slope of about 5% in the grass within 10-ft of the structure). No ponding of surface water should be allowed near the structure.

10.8 Earthwork

10.8.1 General

Difficult access and workability problems can occur in the surficial fat clay fill soils due to poor site drainage, wet season, or site geohydrology. Should this condition develop, drying of the soils for support of pavement and floor slabs may be improved by the addition of 7% lime by dry weight. The application rate corresponding to this additive amount would be approximately 32 pounds per square yard for each six-inch of compacted thickness.

City of Houston Standard Specifications 02336 shall be used as procedural guides for placing, mixing, and compacting lime stabilizer and the soils.

Depending on the major type of soils encountered along the project alignment, lime stabilization of the subgrade soils should most likely be performed. The subgrade soils should be stabilized, using lime based on the City of Houston Specifications, Section 02336. Use 7% lime by dry weight to stabilize the subgrade soils. This results in application rates of 27 and 36 pounds of lime, per square yard per six-inch and eight-inch of compacted thickness, respectively.

Provided the site work is performed during dry weather and/or project schedules permit aeration of wet soils, the subgrade will be suitable for floor slab and pavement support.

10.9 Construction Surveillance

Construction surveillance and quality control tests should be planned to verify materials and placement in accordance with the specifications. The recommendations presented in this report were based on a discrete number of soil test borings. Soil type and properties may vary across the site. As a part of quality control, if this condition is noted during the construction, we can then evaluate and revise the design and construction to minimize construction delays. We recommend the following quality control procedures be followed by a qualified engineer or technician during the construction of the facility:

- Observe the site stripping and proofrolling.
- Verify the compaction of subgrade soils.
- Verify the type, depth and amount stabilizer.
- Evaluate the quality of fill and monitor the fill compaction for all lifts.
- Observe all phases of trench safety.
- Observe all excavation operations.
- Monitor concrete placement, conduct slump tests and make concrete cylinders.

It is the responsibility of the client to notify GET of when each phase of the construction is taking place so that proper quality control and procedures are implemented.

11.0 RECOMMENDED ADDITIONAL STUDIES

This report has been based on assumed conditions/characteristics of the proposed project area where specific information was not available. It is recommended that the architect, civil engineer and structural engineer along with any other design professionals involved in this project carefully review these assumptions to ensure they are consistent with the actual planned development. When discrepancies exist, they should be brought to our attention to ensure they do not affect the conclusions and recommendations provided herein. We recommend that GET be retained to review the plans and specifications to ensure that the geotechnical related conclusions and recommendations provided herein have been correctly interpreted as intended.

12.0 STANDARD OF CARE

The recommendations described herein were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical engineering profession practicing contemporaneously under similar conditions in the locality of the project. No other warranty or guarantee, expressed or implied, is made other than the work was performed in a proper and workmanlike manner.

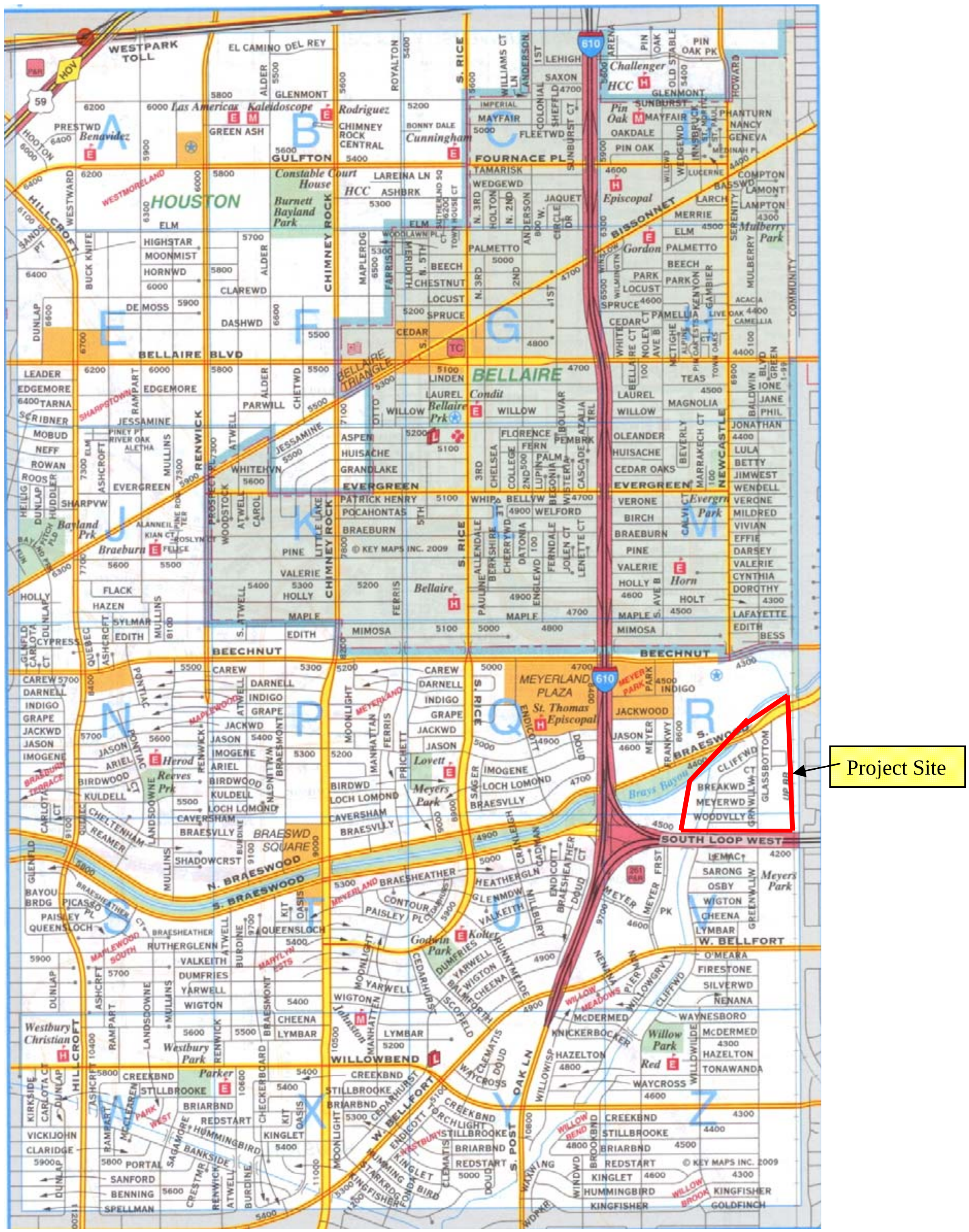
13.0 REPORT DISTRIBUTION

This report was prepared for the sole and exclusive use by our client (Edminster, Hinshaw, Russ and Associates, Inc.) and owner (City of Houston), based on specific and limited objectives. All reports, boring logs, field data, laboratory test results, maps and other documents prepared by GET as instruments of service shall remain the property of GET. GET assumes no responsibility or obligation for the unauthorized use of this report by other parties and for purposes beyond the stated project objectives and work limitations.

14.0 REFERENCES

1. AASHTO Specifications, “Guide for Design of Pavement Structures”, American Association of State Highway and Transportation Officials, 1993.

2. “City of Houston Standard Construction Specifications”, Department of Public Works and Engineering, City of Houston, July 2012.



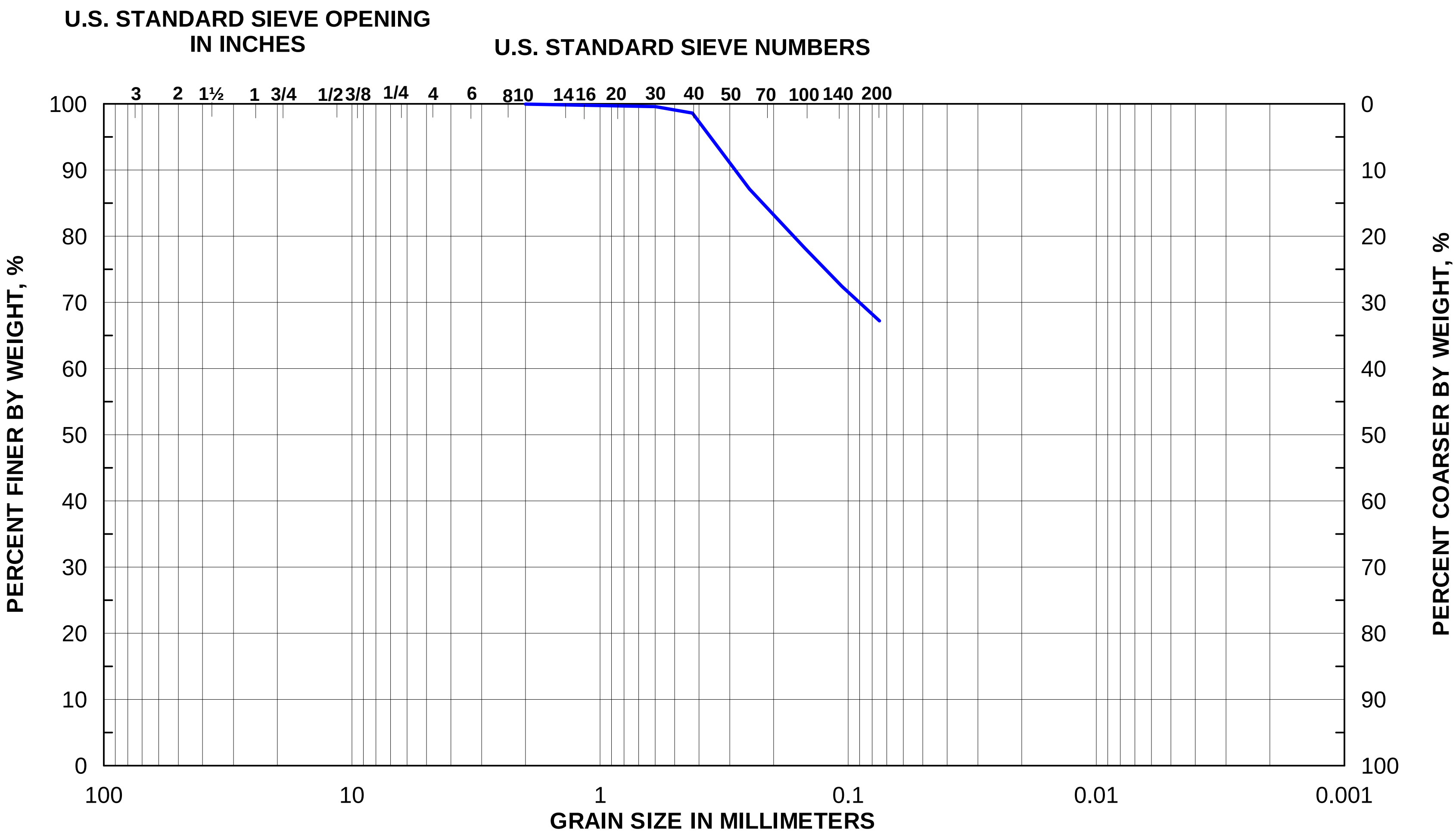
SITE VICINITY MAP			NORTH
PROJECT: Geotechnical Study, Proposed Willow Waterhole Drainage and Paving Improvements WBS No. M-00103-0001-3, City of Houston, Texas			
SCALE: NOT TO SCALE	DATE: MAY 2014	PROJECT NO.: 11-609E	

SUMMARY OF BORING LOCATIONS

Boring No.	Alignment	Northing	Easting	Elevation	Station No.	Offset
B-1	Meyerwood Dr.	13813856.52	3095653.16	47.76	7+40.97	5.45R
B-2	Greenwillow Dr.	13814486.4	3096153.4	46.27	12+36.95	7.08R
B-3	Greenwillow Dr.	13814906.07	3096001.67	47.02	16+57.05	6.34R
B-4	Greenwillow Dr.	13815427.62	3096001.67	51.43	22+02.59	22.71R
B-5	Cliffwood Dr.	13814169.55	3095333.02	46.17	9+85.52	5.02L
B-6	Greenwillow Dr.	13814145.29	3096167.33	47.58	8+95.57	6.17R
B-7	Greenwillow Dr.	13813570.85	3096192.31	48.52	3+20.58	6.13R

EXISTING PAVEMENT THICKNESS

	Thickness, inches	
Core/Boring Locations	Asphalt Pavement	Concrete Pavement
C-1/B-1	−	5.5
C-2/B-2	2.5	6.5
C-3/B-3	1.5	6.5
C-4/B-4	−	7.5
C-5/B-5	2.0	5.5
C-6/B-6	2.5	6.0
C-7/B-7	2.5	5.0



GRAVEL		SAND			SILT	CLAY
Coarse	Fine	Coarse	Medium	Fine		

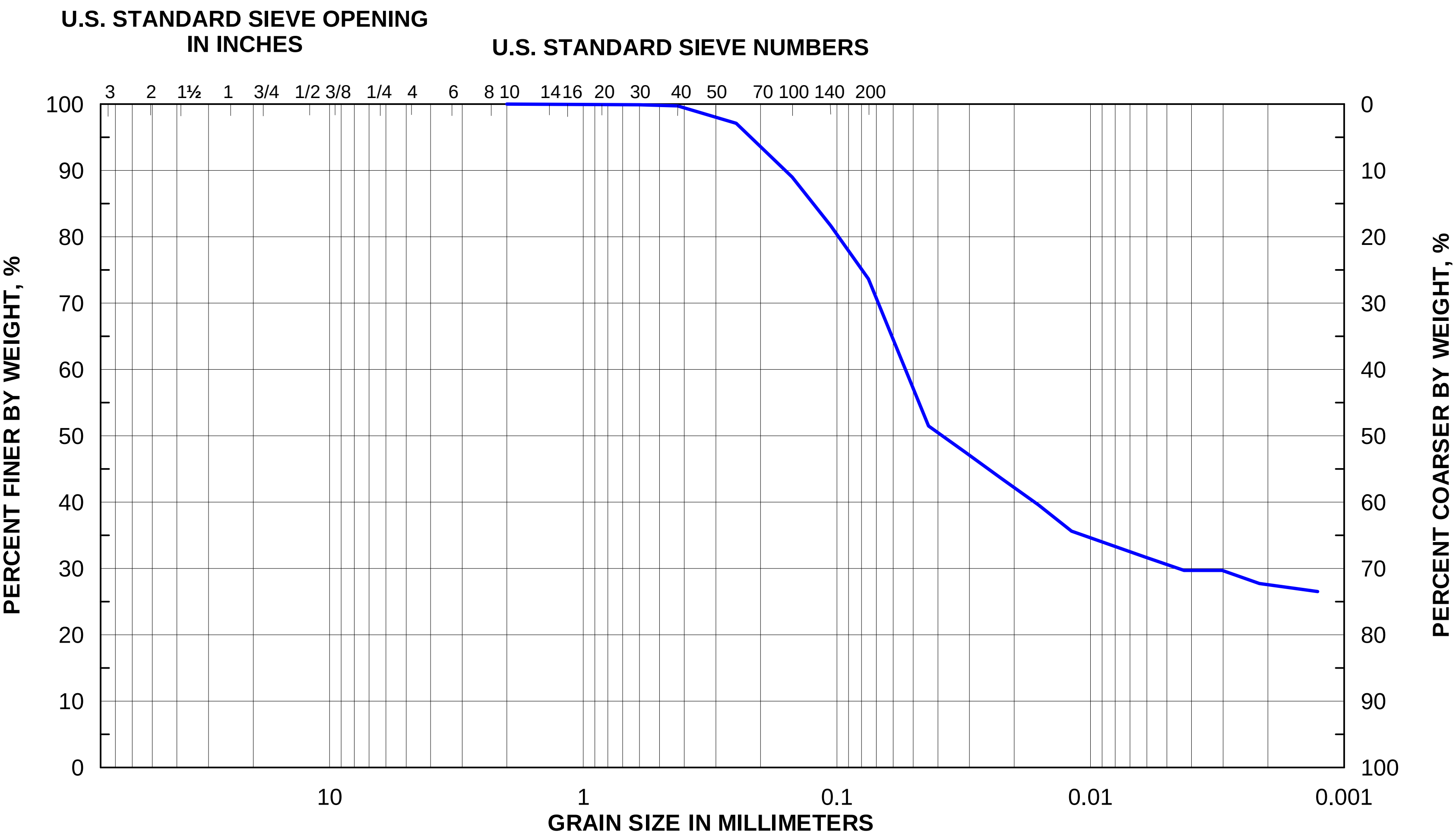
USCS Soil Classification: Sandy Silt (ML)

Percent Passing - #200: 68%

PARTICLE SIZE DISTRIBUTION CURVES FOR B- 2 (14' TO 16')

Project No. 11-609E

GEOTECH ENGINEERING AND TESTING



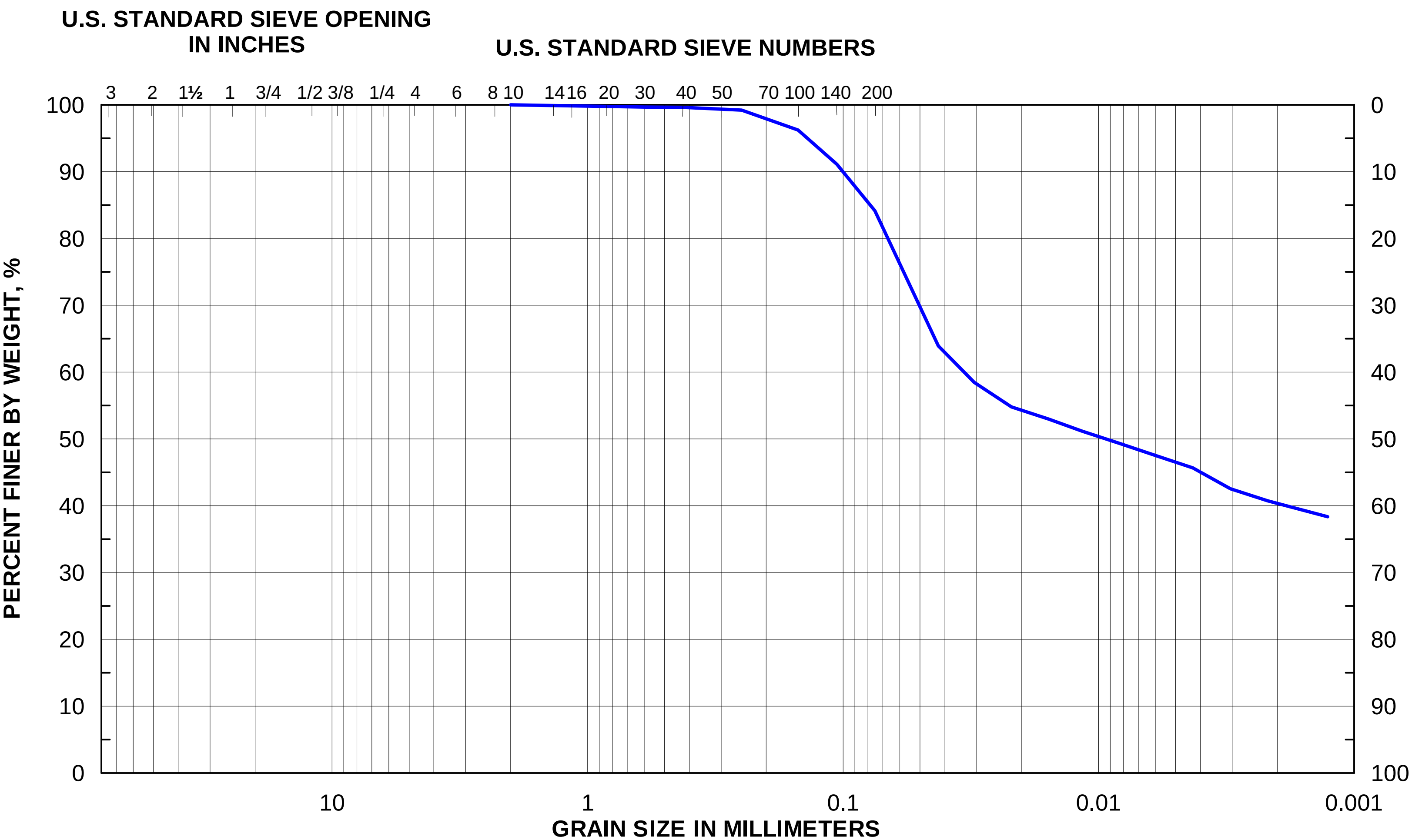
GRAVEL		SAND			SILT	CLAY
Coarse	Fine	Coarse	Medium	Fine		

USCS Soil Classification: Lean Clay with Sand (CL)

-200: 73% Passing

GRAIN SIZE DISTRIBUTION CURVES FOR BORING B-3 (10' TO 12')

Project No. 11-609E



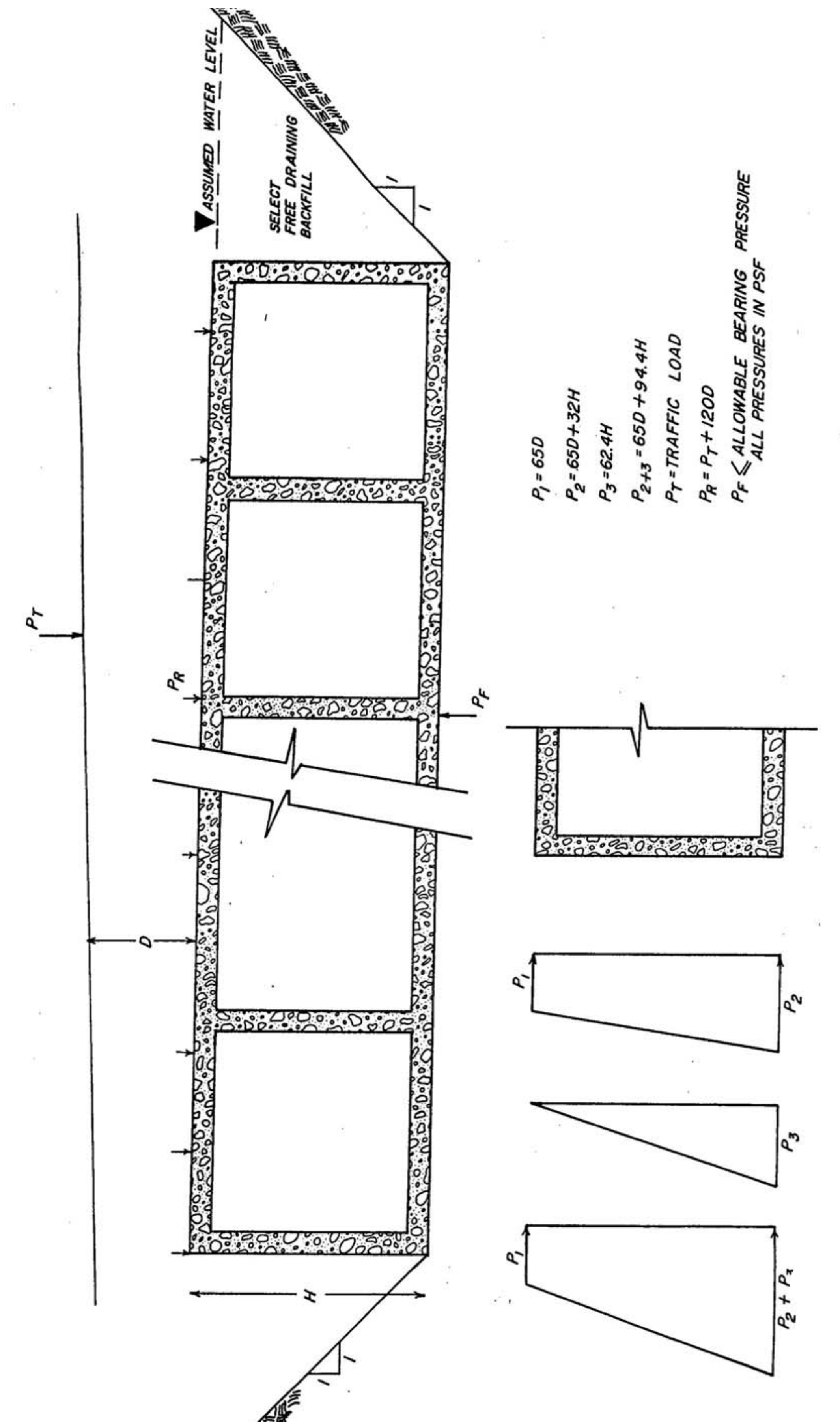
GRAVEL		SAND			SILT	CLAY
Coarse	Fine	Coarse	Medium	Fine		

USCS Soil Classification: Fat Clay (CH)

-200: 84% Passing

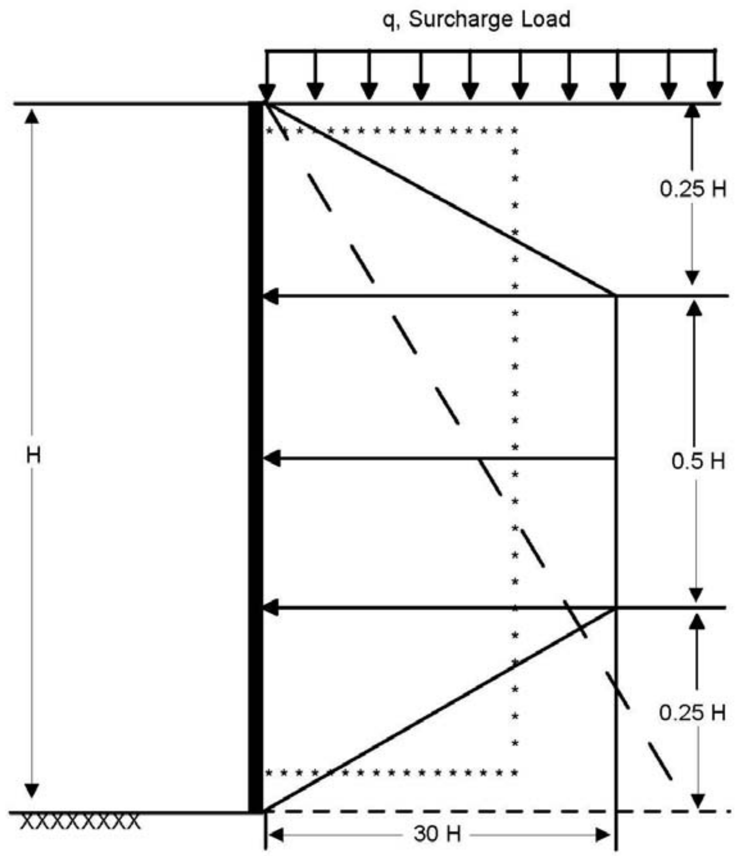
GRAIN SIZE DISTRIBUTION CURVES FOR BORING B-4 (28' TO 30')

Project No. 11-609E



BOX CULVERT DESIGN PARAMETERS

LATERAL EARTH PRESSURE DIAGRAM



Legend:

———————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - - Cantilevered sheeting

Active Pressure:

(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilevered sheeting = 0.7q + 42H + 62.4H

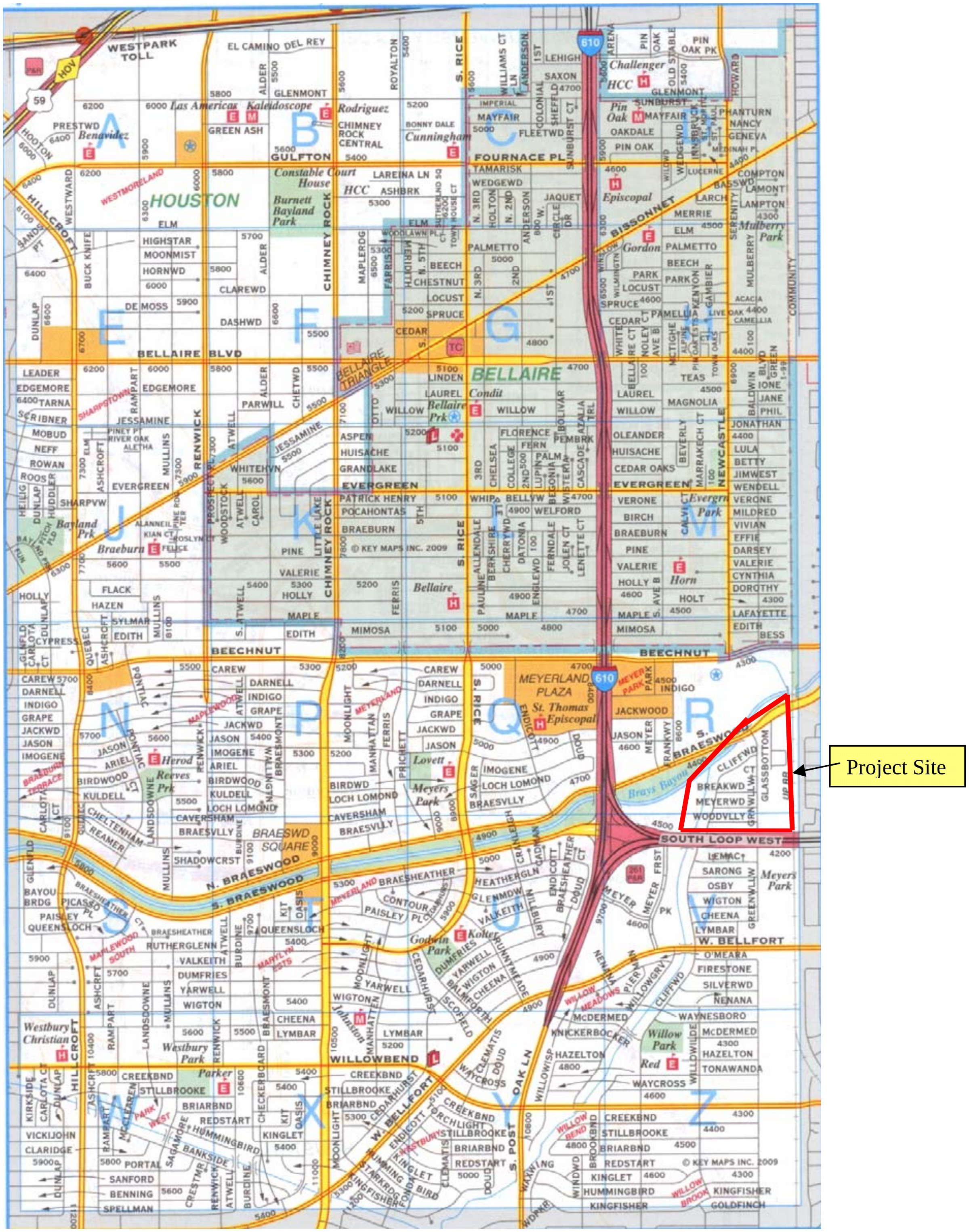
where: q = surcharge load, psf: A value of 250 psf can be assumed.
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.
5. In case of layered soils, active pressure should be calculated based on the dominant or more critical soil conditions.

APPENDIX A

Site Vicinity Map
Plan of Borings
Soil Stratigraphy
Logs of Borings
Key to Log Terms and Symbols
Summary of Laboratory Test Results

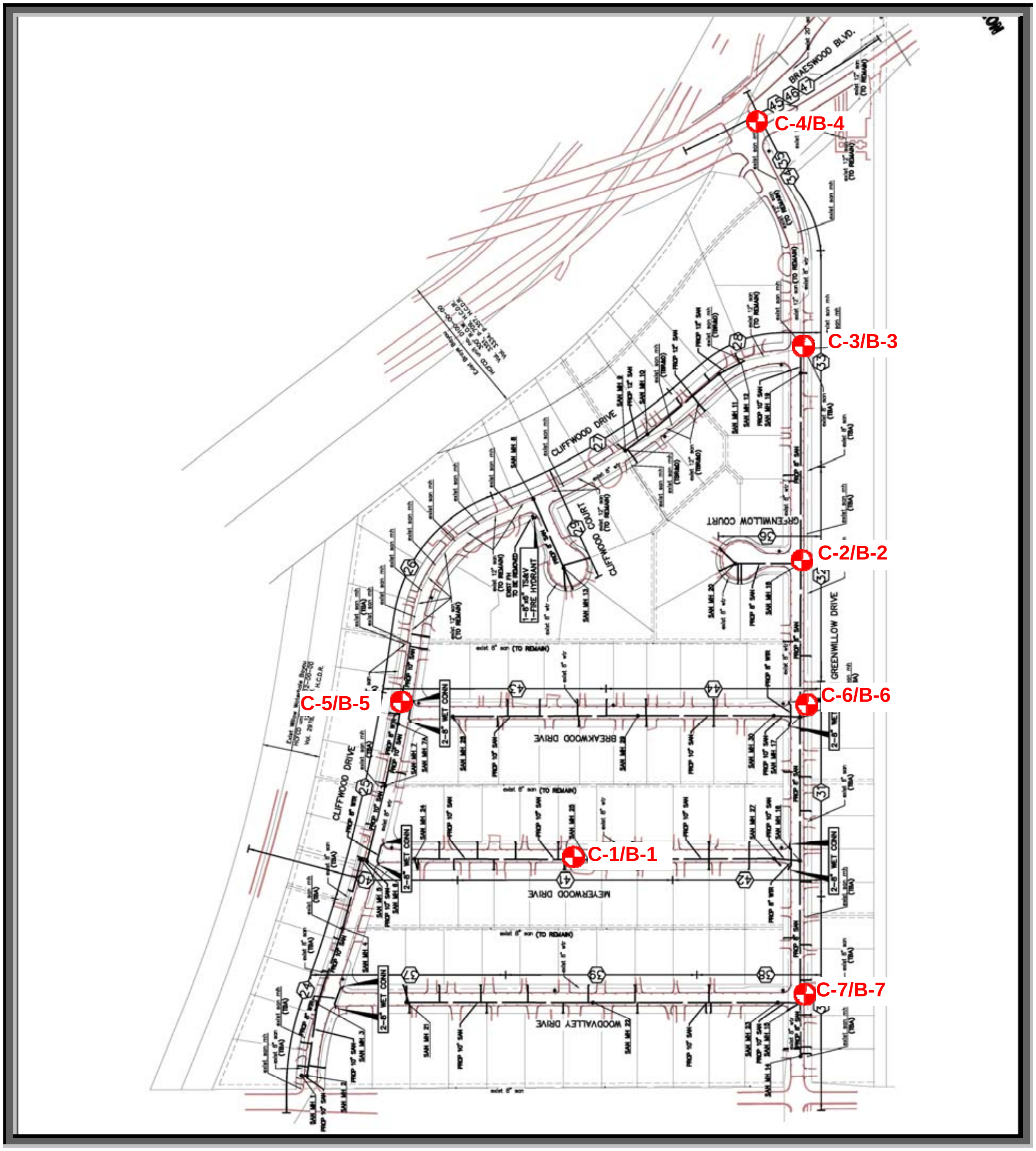


SITE VICINITY MAP

PROJECT: Geotechnical Study, Proposed Willow Waterhole Drainage and Paving Improvements
WBS No. M-00103-0001-3, City of Houston, Texas

SCALE: NOT TO SCALE	DATE: MAY 2014	PROJECT NO.: 11-609E

NORTH



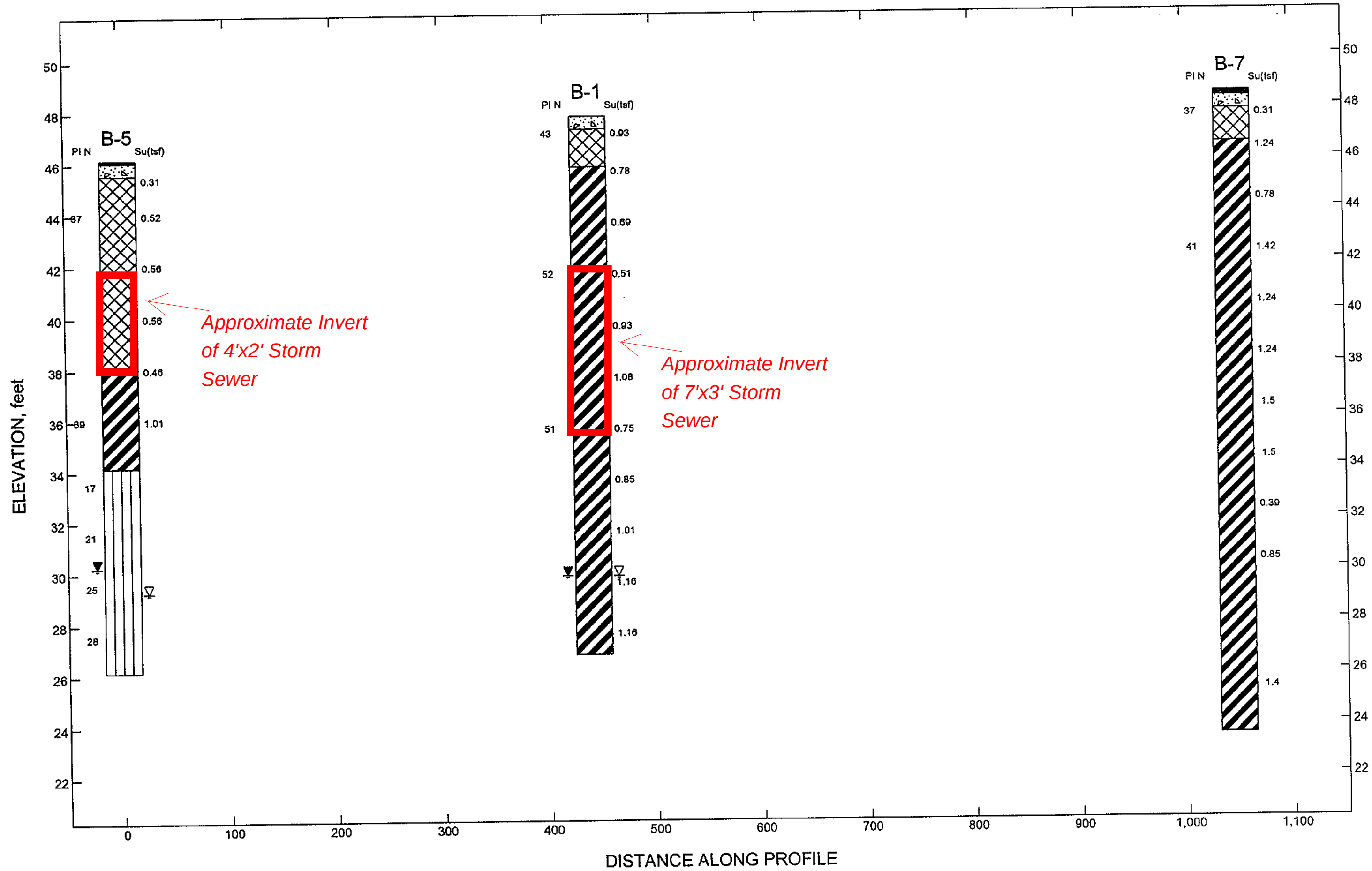
Legend: B-1: Soil Boring Location
C-1: Concrete Coring Location

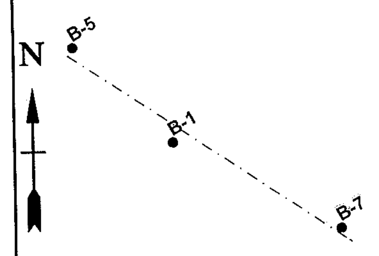
PLAN OF BORINGS

PROJECT: Geotechnical Study, Proposed Willow Waterhole Drainage and Paving Improvements, WBS No. M-001013-0001-3, City of Houston, Texas

SCALE: 1"=100'	DATE: MAY 2014	PROJECT NO.: 11-609E

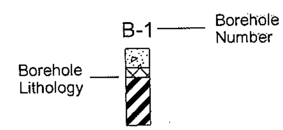
NORTH





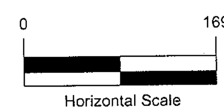
Site Map Scale 1 inch equals 620 feet

Explanation



Water Level Reading at time of drilling.

Water Level Reading after drilling.



Vertical Exaggeration: 24x

Lithology Graphics

Concrete

Fill: Fat Clay (CH)

Fat Clay (CH)

Asphalt

Sandy Silt (ML)

Proposed Storm Sewer

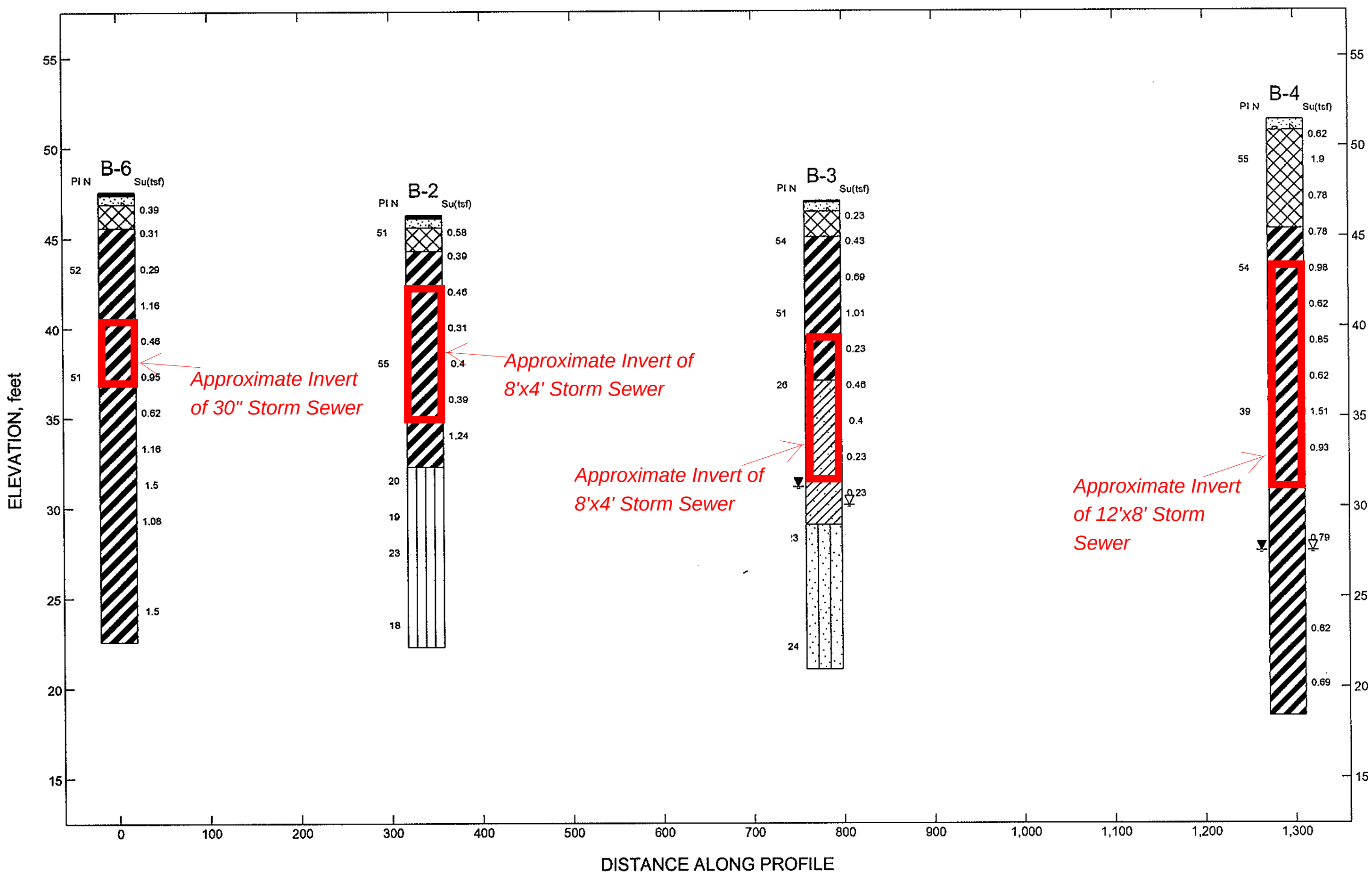
Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022

Proposed Willow Waterhole Drainage and Paving Improvements

City of Houston, Texas

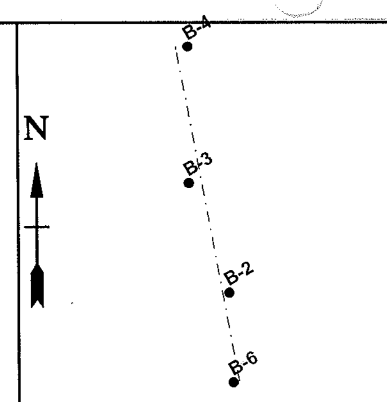
JOB NUMBER	PLATE NUMBER
M-001013-0001-3	PLATE A-3

BERNARD 11-609E.GPJ FANWNL01.GDT 1/16/14



Lithology Graphics

- Asphalt
- Concrete
- Fill: Fat Clay (CH)
- Fat Clay (CH)
- Sandy Silt (ML)
- Lean Clay with Sand (CL)
- Silty Sand (SM)
- Proposed Storm Sewer



Site Map Scale 1 inch equals 735 feet

Explanation

B-2 — Borehole Number

Borehole Lithology

Water Level Reading at time of drilling.

Water Level Reading after drilling.

0 200

Horizontal Scale

Vertical Exaggeration: 20x

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022

Proposed Willow Waterhole Drainage and Paving Improvements

City of Houston, Texas

JOB NUMBER	PLATE NUMBER
M-001013-0001-3	PLATE A-4

BERNARD 11-609E.GPJ FANWNL01.GDT 1/16/14

LOG OF BORING NO. B-1

GET GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 7+40.97
DATE: 12-19-13 COMPLETION DEPTH: 21.0 ft.

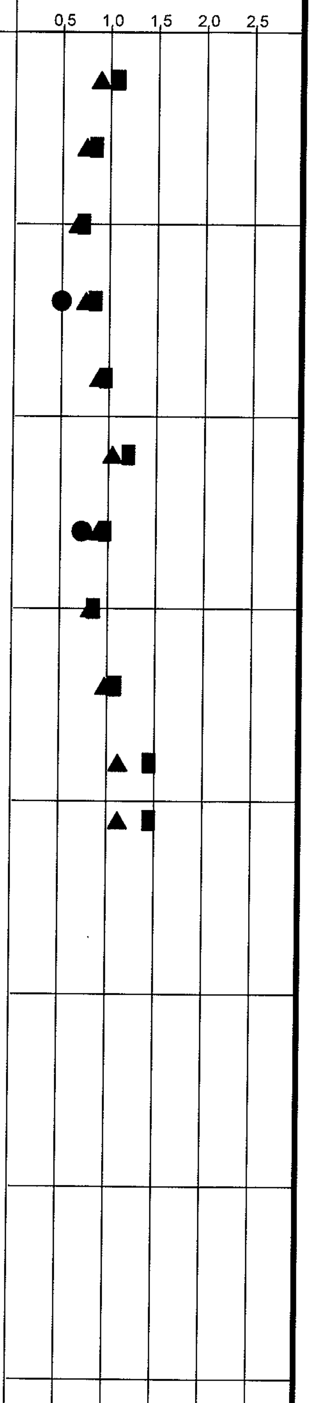
ELEVATION: 47.76
NORTHING: 13813570.85
EASTING: 3096192.31
OFFSET: 5.45R

DESCRIPTION

- CONCRETE PAVEMENT (5.5")
- FILL: FAT CLAY (CH), stiff, dark brown, with root fibers, ferrous and calcareous nodules
- FAT CLAY (CH), stiff, dark brown, with root fibers to 4', ferrous and calcareous nodules
  - dark gray 4' to 8'
  - light brown, light gray 8' to 20'
  - very stiff 10' to 12'
  - very stiff 16' to 21'

NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
34	64	21	43	89				
34								
35								
37	75	23	52			85		
37								
33								
35	73	22	51	94		85		
35								
36								
40								
36								

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
▽: WATER ENCOUNTERED AT 18.0 ft. DURING DRILLING
▼: WATER DEPTH AT 18.0 ft. AFTER 24-HOUR

DRY AUGER: 0 TO 18 ft.
WET ROTARY: 18 TO 21 ft.

DRILLED BY: GET
LOGGED BY: BJ

OVM2 11-609E.GPJ OVM.GDT 1/16/14

LOG OF BORING NO. B-2

Sheet 1 of 1

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 12+36.95
DATE: 12-20-13 COMPLETION DEPTH: 24.0 ft.

ELEVATION: 46.27
NORTHING: 13814486.40
EASTING: 3096153.40
OFFSET: 7.08R

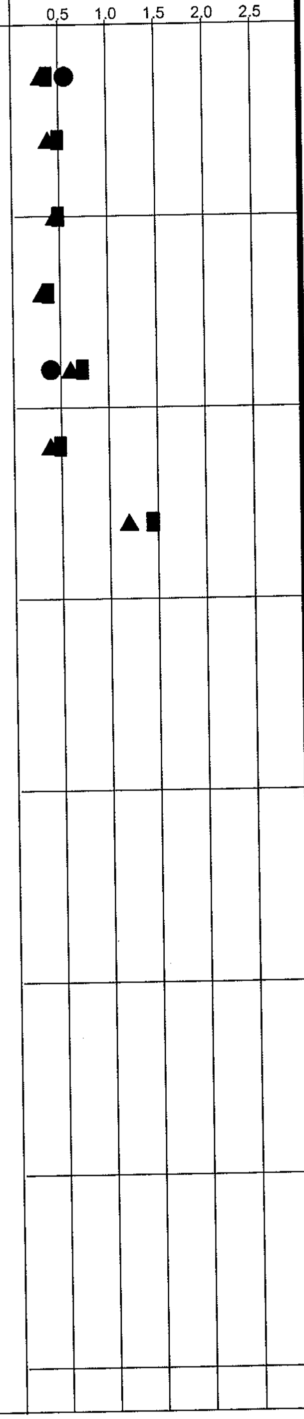
DESCRIPTION

- ASPHALT PAVEMENT (2.5")
- CONCRETE PAVEMENT (6.5")
- FILL: FAT CLAY (CH), stiff, gray, with root fibers, ferrous and calcareous nodules
- FAT CLAY (CH), firm, gray, light gray, with root fibers to 4', ferrous and calcareous nodules
  - very stiff 12' to 14'
- SANDY SILT (ML), medium dense, light brown, brown

DEPTH, ft (approx.)	SPT N-VALUE blows per foot	OVM, ppm	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
1			36	73	22	51	93		88		
3			30								
5			33								
7			35								
9			25	78	23	55	90		90		
11			32								
13			23								
15	20		29				68				
17	19		21								
19	23		27								
23	18		19								

UNDRAINED SHEAR STRENGTH, tsf

▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 24 ft.
WET ROTARY: ___ TO ___ ft.

DRILLED BY: GET
LOGGED BY: BJ

LOG OF BORING NO. B-3

Sheet 1 of 1

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 16+57.05
DATE: 12-19-13 COMPLETION DEPTH: 26.0 ft.

ELEVATION: 47.02
NORTHING: 13814906.07
EASTING: 3096134.39
OFFSET: 6.34R

DESCRIPTION

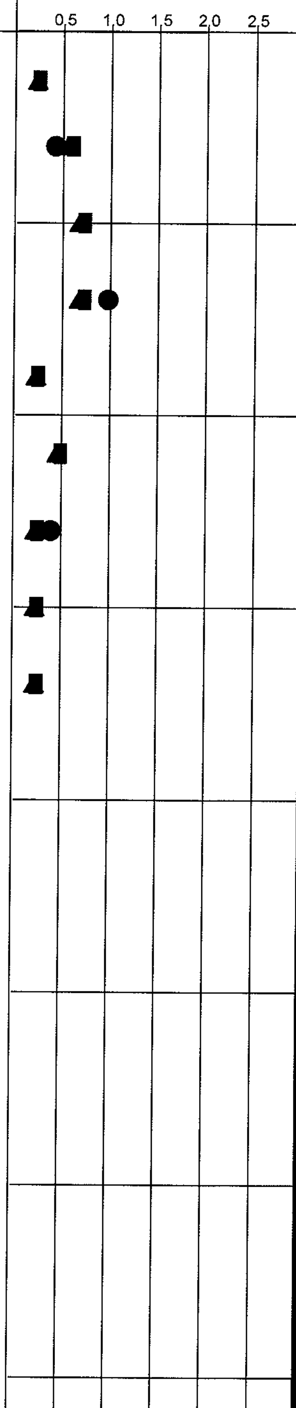
- ASPHALT PAVEMENT (1.5")
- CONCRETE PAVEMENT (6.5")
- FILL: FAT CLAY, soft, dark gray, with root fibers, ferrous and calcareous nodules
- FAT CLAY (CH), firm, dark gray, dark brown, with root fibers to 4', ferrous and calcareous nodules
  - stiff 4' to 6'
  - very stiff 6' to 8'
  - soft 8' to 10'
- LEAN CLAY WITH SAND (CL), firm, light gray, dark gray, with ferrous nodules
  - soft 12' to 18'
- SILTY SAND (SM), medium dense, reddish brown

SPT N-VALUE blows per foot	OVM, ppm	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
		26								
		28	77	23	54			91		
		30								
		29	74	23	51	84		97		
		28								
		32	44	18	26	73		97		
		27								
		49								
		45								
23		17				36				
24		19								

DEPTH, ft: 0, 5, 10, 15, 20, 25, 30, 35

UNDRAINED SHEAR STRENGTH, tsf

▲ HAND PENETROMETER
▮ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
∇: WATER ENCOUNTERED AT 17.0 ft. DURING DRILLING
▼: WATER DEPTH AT 16.0 ft. AFTER 24-HOUR

DRY AUGER: 0 TO 18 ft.
WET ROTARY: 18 TO 26 ft.

DRILLED BY: GET
LOGGED BY: BJ

OVM2 11-609E.GPJ OVM.GDT 1/16/14

LOG OF BORING NO. B-4

GET GEOTECH ENGINEERING & TESTING

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 22+02.59
DATE: 12-23-13 COMPLETION DEPTH: 33.0 ft.

ELEVATION: 51.43
NORTHING: 13815427.62
EASTING: 3096001.67
OFFSET: 22.71R

Note: Boring B-4 was moved from its original location due to obstruction encountered at a depth of about 7-ft.

Columns: DEPTH, ft | SPT N-VALUE blows per foot | OVM, ppm | SYMBOL | SAMPLES | DESCRIPTION | NATURAL MOISTURE CONTENT, % | LIQUID LIMIT, % | PLASTIC LIMIT, % | PLASTICITY INDEX, % | PERCENT PASSING NO. 200 SIEVE | SUCTION (pF) | DRY UNIT WEIGHT, pcf | PERCENT COMPACTION | PASSING/FAILING (P/F) | UNDRAINED SHEAR STRENGTH, tsf

DESCRIPTION

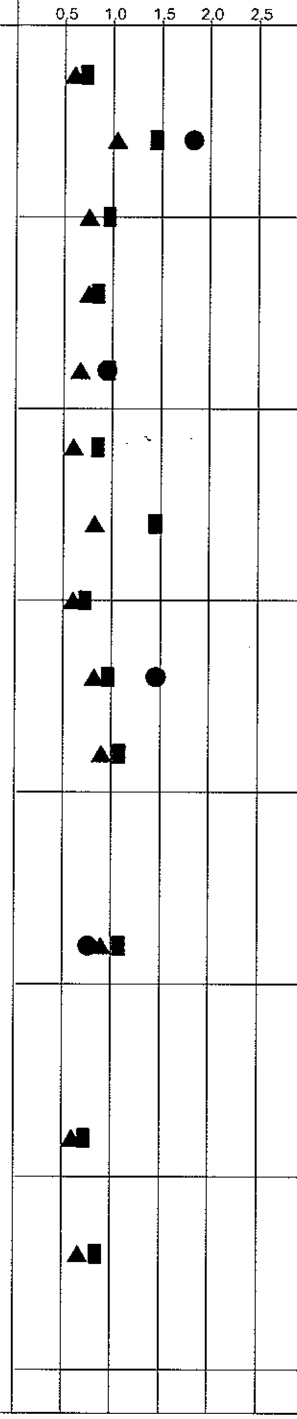
CONCRETE PAVEMENT (7.5")

FILL: FAT CLAY (CH), stiff, dark brown, with root fibers to 6', ferrous and calcareous nodules
- very stiff 2' to 4'

FAT CLAY (CH), stiff, dark brown, gray, with ferrous and calcareous nodules
- very stiff 16' to 18'
- light brown, gray 18' to 33'

Natural Moisture Content, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Percent Passing No. 200 Sieve	Suction (pF)	Dry Unit Weight, pcf	Percent Compaction	Passing/Failing (P/F)
23								
25	80	25	55	88		107		
23								
27								
29	78	24	54	94		94		
26								
24								
21								
23	58	19	39	87		108		
18								
18						109		
20				84				
19								

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 24.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 24.0 ft. AFTER 24-HOUR

DRY AUGER: 0 TO 24 ft.
WET ROTARY: 24 TO 33 ft.

DRILLED BY: GET
LOGGED BY: BJ

OVM2 11-609E.GPJ OVM.GDT 1/16/14

LOG OF BORING NO. B-5

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

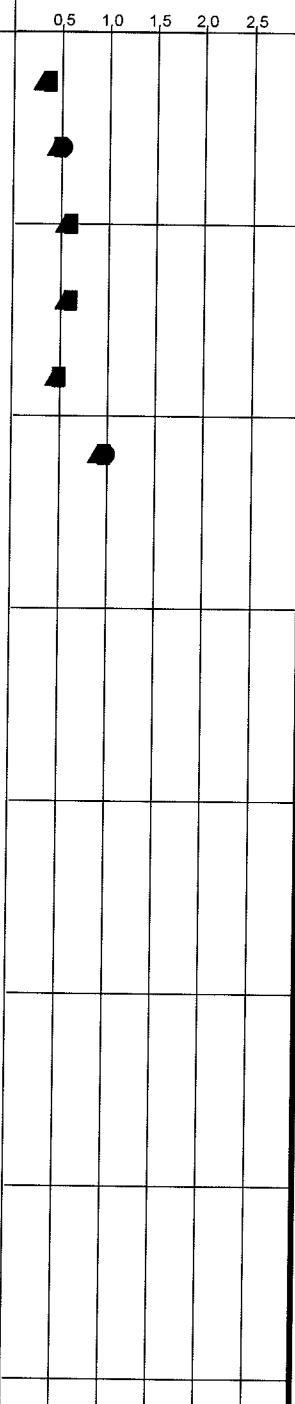
PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 9+85.52
DATE: 12-19-13 COMPLETION DEPTH: 20.0 ft.

ELEVATION: 46.17
NORTHING: 13814169.55
EASTING: 3095333.02
OFFSET: 5.02L

SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
		ASPHALT PAVEMENT (2.0")									
		CONCRETE PAVEMENT (5.5")									
		FILL: FAT CLAY (CH), firm, dark gray, light gray, with root fibers to 4', ferrous and calcareous nodules	30								
		- stiff 2' to 8'	24	57	20	37			100		
			24								
			25								
		FAT CLAY (CH), firm, brown, gray, with ferrous and calcareous nodules	28								
		- very stiff 10' to 12'	24	59	20	39			99		
17		SANDY SILT (ML), medium dense, gray	27								
21			26								
25			24				69				
28			21								

DEPTH, ft: 0, 5, 10, 15, 20, 25, 30, 35

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 17.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 16.0 ft. AFTER 24-HOUR

DRY AUGER: 0 TO 18 ft.
WET ROTARY: 18 TO 20 ft.

DRILLED BY: GET
LOGGED BY: BJ

OVM2 11-609E.GPJ OVM.GDT 1/16/14

LOG OF BORING NO. B-6

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 8+95.57
DATE: 12-20-13 COMPLETION DEPTH: 25.0 ft.

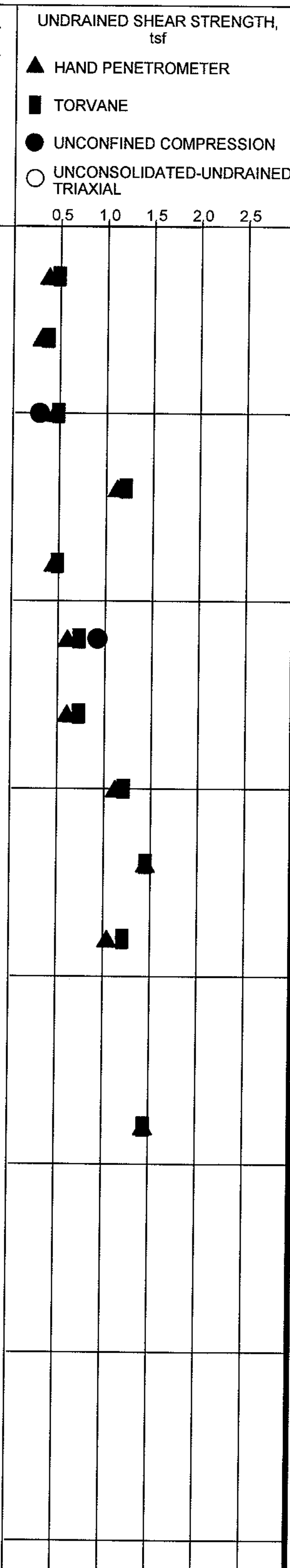
ELEVATION: 47.58
NORTHING: 13814145.29
EASTING: 3096167.33
OFFSET: 6.17R

Columns: DEPTH, ft | SPT N-VALUE blows per foot | OVM, ppm | SYMBOL | SAMPLES | DESCRIPTION | NATURAL MOISTURE CONTENT, % | LIQUID LIMIT, % | PLASTIC LIMIT, % | PLASTICITY INDEX, % | PERCENT PASSING NO. 200 SIEVE | SUCTION (pF) | DRY UNIT WEIGHT, pcf | PERCENT COMPACTION | PASSING/FAILING (P/F)

DESCRIPTION

ASPHALT PAVEMENT (2.5")
CONCRETE PAVEMENT (6.0")
FILL: FAT CLAY (CH), firm, gray, with root fibers ', ferrous and calcareous nodules
FAT CLAY (CH), firm, gray, light gray, with root fibers to 4', ferrous and calcareous nodules
- soft 4' to 6'
- very stiff 6' to 8'
- stiff 10' to 14'
- reddish brown 12' to 25'
- very stiff 14' to 25'

NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
28								
32								
32	75	23	52	93		92		
25								
33								
28	75	24	51	95		94		
34								
20								
20								
27								
17								



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 25 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: GET
LOGGED BY: BJ

LOG OF BORING NO. B-7

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Proposed Willow Waterhole Drainage and Paving Improvements
LOCATION: City of Houston, Texas
PROJECT NO.: M-001013-0001-3 STATION NO.: 3+20.58
DATE: 12-19-13 COMPLETION DEPTH: 25.0 ft.

ELEVATION: 48.52
NORHTING: 13813570.85
EASTING: 3096192.31
OFFSET: 6.13R

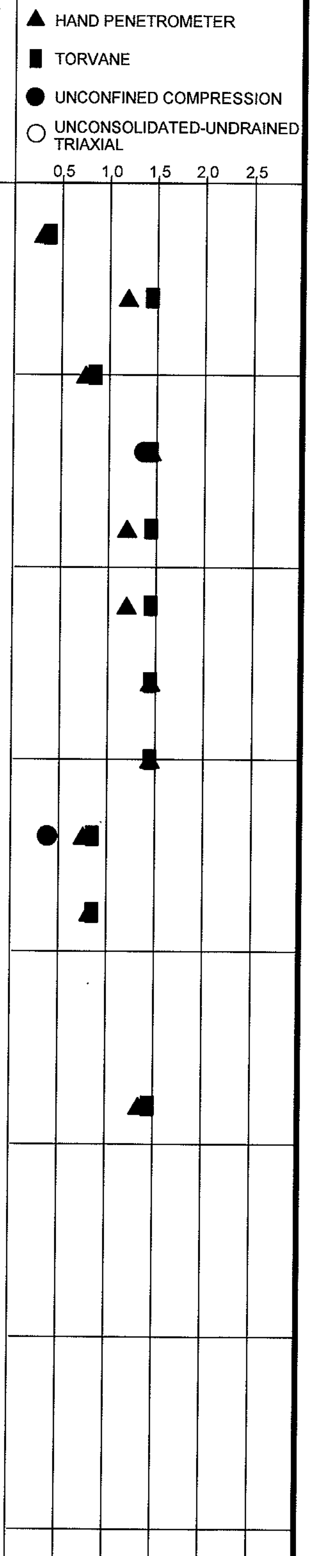
Columns: DEPTH, ft | SPT N-VALUE blows per foot | OVM, ppm | SYMBOL | SAMPLES

DESCRIPTION

ASPHALT PAVEMENT (2.5")
CONCRETE PAVEMENT (5.0")
FILL: FAT CLAY (CH), firm, dark gray, with root fibers, ferrous and calcareous nodules
FAT CLAY (CH), very stiff, light gray, gray, with root fibers to 4', ferrous and calcareous nodules
- stiff 4' to 6'
- firm 16' to 18'
- stiff 18' to 20'

NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
31	57	20	37					
24								
25								
24	61	20	41	88		98		
27								
25								
22								
21								
30						94		
27								
18								

UNDRAINED SHEAR STRENGTH, tsf



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 25 ft.
WET ROTARY: ___ TO ___ ft.

DRILLED BY: GET
LOGGED BY: BJ

OVM2 11-609E.GPJ OVM.GDT 1/16/14

KEY TO LOG TERMS AND SYMBOLS

UNIFIED SOIL CLASSIFICATIONS

Symbol		Material Descriptions
GW		WELL GRADED-GRAVELS, GRAVEL-SAND MIXTURES LITTLE OR NO FINES
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM		SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
GC		CLAY GRAVELS, GRAVEL-SAND CLAY MIXTURES
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP		POORLY GRADED SANDS, OR GRAVELLY SANDS, LITTLE OR NO FINES
SM		SILTY SANDS, SAND-SILT MIXTURES a
SC		CLAYEY SANDS, SAND-SILT MIXTURES b
ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS
OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
PT		PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENT
		FILL SOILS

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	-	Having incline planes of weakness that are slick and glossy in appearance.
Fissured	-	Containing shrinkage cracks frequently filled with fine sand or silt: usually vertical.
Laminated	-	Composed of thin layers of varying colors and soil sample texture.
Interbedded	-	Composed of alternate layers of different soil types.
Calcareous	-	Containing appreciable quantities of calcium carbonate.
Well Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly Graded	-	Predominantly of one grain size, or having a range of sizes with some intermediate sizes missing.
Pocket	-	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	-	Inclusion less than ⅛-inch thick extending through the sample.
Seam	-	Inclusion ⅛- to 3-inch thick extending through the sample.
Layer	-	Inclusion greater than 3-inch thick extending through the sample.
Interlayered	-	Soils sample composed of alternating layers of different soil types.
Intermixed	-	Soil samples composed of pockets of different soil type and layered or laminated structure is not evident.

COARSE GRAINED SOILS (major portion retained on No. 200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Conditions rated according to standard penetration test (SPT)* as performed in the field.

Descriptive Terms	Blows Per Foot*
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	over 50

* 140 pound weight having a free fall of 30-inch

FINE GRAINED SOILS (major portion passing No. 200 Sieve): Include (1) inorganic or organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by hand penetrometer readings or by unconfined compression tests.

Descriptive Term	Undrained Shear Strength Ton/Sq. Ft.
Very Soft	Less than 0.13
Soft	0.13 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 or higher

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of weakness or cracks in the soil. The consistency ratings of such soils are based on hand penetrometer readings.

SOIL SAMPLERS

- SHELBY TUBE SAMPLER
- STANDARD PENETRATION TEST
- AUGER SAMPLING

TERMS CHARACTERIZING ROCK PROPERTIES

VERY SOFT OR PLASTIC	Can be remolded in hand: corresponds in consistency up to very stiff in soils.
SOFT	Can be scratched with fingernail.
MODERATELY HARD	Can be scratched easily with knife; cannot be scratched with fingernail.
	Difficult to scratch with knife.
VERY HARD	Cannot be scratched with knife.
POORLY CEMENTED OR FRIABLE	Easily crumbled.
CEMENTED	Bounded Together by chemically precipitated materials.
UNWEATHERED	Rock in its natural state before being exposed to atmospheric agents.
SLIGHTLY WEATHERED	Noted predominantly by color change with no disintegrated zones.
WEATHERED	Complete color change with zones of slightly decomposed rock.
EXTREMELY WEATHERED	Complete color change with consistency, texture, and general appearance or soil.

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-1	1	0	0.5													Concrete Pavement
	2	0.5	2	UD		34		64	21	43	89			1.12	0.93	Fill: Fat Clay (CH)
	3	2	4	UD		34								0.88	0.78	Fat Clay (CH)
	4	4	6	UD		35								0.75	0.69	Fat Clay (CH)
	5	6	8	UD		37	85	75	23	52		0.51		0.88	0.78	Fat Clay (CH)
	6	8	14	UD		37								1	0.93	Fat Clay (CH)
	7	10	12	UD		33								1.25	1.08	Fat Clay (CH)
	8	12	14	UD		35	85	73	22	51	94	0.75		1	0.93	Fat Clay (CH)
	9	14	16	UD		35								0.88	0.85	Sandy Silt (ML)
	10	16	18	UD		36								1.12	1.01	Sandy Silt (ML)
	11	18	20	UD		40								1.5	1.16	Sandy Silt (ML)
	12	20	21	UD		36								1.5	1.16	Sandy Silt (ML)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

PLATE A-13

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-2	1	0	0.2													Asphalt Pavement
	2	0.2	0.7													Concrete Pavement
	3	0.7	2	UD		36	88	73	22	51	93	0.58		0.38	0.31	Fill: Fat Clay (CH)
	4	2	4	UD		30								0.5	0.39	Fat Clay (CH)
	5	4	6	UD		33								0.5	0.46	Fat Clay (CH)
	6	6	8	UD		35								0.38	0.31	Fat Clay (CH)
	7	8	10	UD		25	90	78	23	55	90	0.4		0.75	0.62	Fat Clay (CH)
	8	10	12	UD		32								0.5	0.39	Fat Clay (CH)
	9	12	14	UD		23								1.5	1.24	Fat Clay (CH)
	10	14.5	16	SS	20	29					68					Sandy Silt (ML)
	11	16.5	18	SS	19	21										Sandy Silt (ML)
	12	18.5	20	SS	23	27										Sandy Silt (ML)
	13	22.2	24	SS	18	19										Sandy Silt (ML)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-3	1	0	0.1													Asphalt Pavement
	2	0.1	0.7													Concrete Pavement
	3	0.7	2	UD		26								0.25	0.23	Fill: Fat Clay (CH)
	4	2	4	UD		28	91	77	23	54		0.43		0.62	0.56	Fat Clay (CH)
	5	4	6	UD		30								0.75	0.69	Fat Clay (CH)
	6	6	8	UD		29	97	74	23	51	84	1.01		0.75	0.69	Fat Clay (CH)
	7	8	10	UD		28								0.25	0.23	Fat Clay (CH)
	8	10	12	UD		32	97	44	18	26	73			0.5	0.46	Fat Clay (CH)
	9	12	14	UD		27						0.4		0.25	0.23	Fat Clay (CH)
	10	14	16	UD		49								0.25	0.23	Fat Clay (CH)
	11	16	18	UD		45								0.25	0.23	Fat Clay (CH)
	12	18.5	20	SS	23	17					36					Silty Sand (SM)
	13	24.5	26	SS	24	19										Silty Sand (SM)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT)		TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
		Top	Bottom													
B-4	1	0	0.6													Concrete Pavement
	2	0.6	2	UD		23								0.75	0.62	Fill: Fat Clay (CH)
	3	2	4	UD		25	107	80	25	55	88	1.9		1.5	1.08	Fill: Fat Clay (CH)
	4	4	6	UD		23								1	0.78	Fill: Fat Clay (CH)
	5	6	8	UD		27								0.88	0.78	Fat Clay (CH)
	6	8	14	UD		29	94	78	24	54	94	0.98		1	0.69	Fat Clay (CH)
	7	10	12	UD		26								0.88	0.62	Fat Clay (CH)
	8	12	14	UD		24								1.5	0.85	Fat Clay (CH)
	9	14	16	UD		21								0.75	0.62	Fat Clay (CH)
	10	16	18	UD		23	108	58	19	39	87	1.51		1	0.85	Fat Clay (CH)
	11	18	20	UD		18								1.12	0.93	Fat Clay (CH)
	12	23	26	UD		18	109					0.79		1.12	0.93	Fat Clay (CH)
	13	28	30	UD		20					84			0.75	0.62	Fat Clay (CH)
	14	31	33	UD		19								0.88	0.69	Fat Clay (CH)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

PLATE A-16

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-5	1	0	0.1													Asphalt Pavement
	2	0.1	0.6													Concrete Pavement
	3	0.6	2	UD		30								0.38	0.31	Fill: Fat Clay (CH)
	4	2	4	UD		24	100	57	20	37		0.52		0.5	0.46	Fill: Fat Clay (CH)
	5	4	6	UD		24								0.62	0.56	Fill: Fat Clay (CH)
	6	6	8	UD		25								0.62	0.56	Fill: Fat Clay (CH)
	7	8	10	UD		28								0.5	0.46	Fat Clay (CH)
	8	10	12	UD		24	99	59	20	39		1.01		1	0.93	Fat Clay (CH)
	9	12.5	14	SPT	17	27										Sandy Silt (ML)
	10	14.5	16	SPT	21	26										Sandy Silt (ML)
	11	16.5	18	SPT	25	24					69					Sandy Silt (ML)
	12	18.5	20	SPT	28	21										Sandy Silt (ML)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

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NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE NO.	SAMPLE DEPTH (FT) Top	SAMPLE DEPTH (FT) Bottom	SAMPLE TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-6	1	0	0.2													Asphalt Pavement
	2	0.2	0.7													Concrete Pavement
	3	0.7	2	UD		28								0.5	0.39	Fill: Fat Clay (CH)
	4	2	4	UD		32								0.38	0.31	Fat Clay (CH)
	5	4	6	UD		32	92	75	23	52	93	0.29		0.5	0.46	Fat Clay (CH)
	6	6	8	UD		25								1.25	1.16	Fat Clay (CH)
	7	8	10	UD		33								0.5	0.46	Fat Clay (CH)
	8	10	12	UD		28	94	75	24	51	95	0.95		0.75	0.62	Fat Clay (CH)
	9	12	14	UD		34								0.75	0.62	Fat Clay (CH)
	10	14	16	UD		20								1.25	1.16	Fat Clay (CH)
	11	16	18	UD		20								1.5	1.5	Fat Clay (CH)
	12	18	20	UD		27								1.25	1.08	Fat Clay (CH)
	13	23	25	UD		17								1.5	1.5	Fat Clay (CH)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

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SPT = STANDARD PENETRATION TEST

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NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: PROPOSED WILLOW WATERHOLE DRAINAGE AND PAVING

COH WBS NUMBER: M-001013-0001-3

CONSULTANT PROJECT NUMBER: 11-609E

BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-12	1	0	0.2													Asphalt Pavement
	2	0.2	0.7													Concrete Pavement
	3	0.7	2	UD		31		57	20	37				0.38	0.31	Fill: Fat Clay (CH)
	4	2	4	UD		24								1.5	1.24	Fat Clay (CH)
	5	4	6	UD		25								0.88	0.78	Fat Clay (CH)
	6	6	8	UD		24	98	61	20	41	88	1.42		1.5	1.5	Fat Clay (CH)
	7	8	10	UD		27								1.5	1.24	Fat Clay (CH)
	8	10	12	UD		25								1.5	1.24	Fat Clay (CH)
	9	12	14	UD		22								1.5	1.5	Fat Clay (CH)
	10	14	16	UD		21								1.5	1.5	Fat Clay (CH)
	11	16	18	UD		30					94	0.39		0.88	0.78	Fat Clay (CH)
	12	18	20	UD		27								0.88	0.85	Fat Clay (CH)
	13	23	25	UD		18								1.5	1.4	Fat Clay (CH)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

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NOTES:

APPENDIX B

Project Site Pictures

PROJECT PICTURES
Project No. 11-609E

P-1 (A Picture of Project Alignment along Greenwillow Dr.

P-2 (A Picture of Coring and Traffic Control)

P-3 (A Picture of Drilling Operations and Traffic Control)

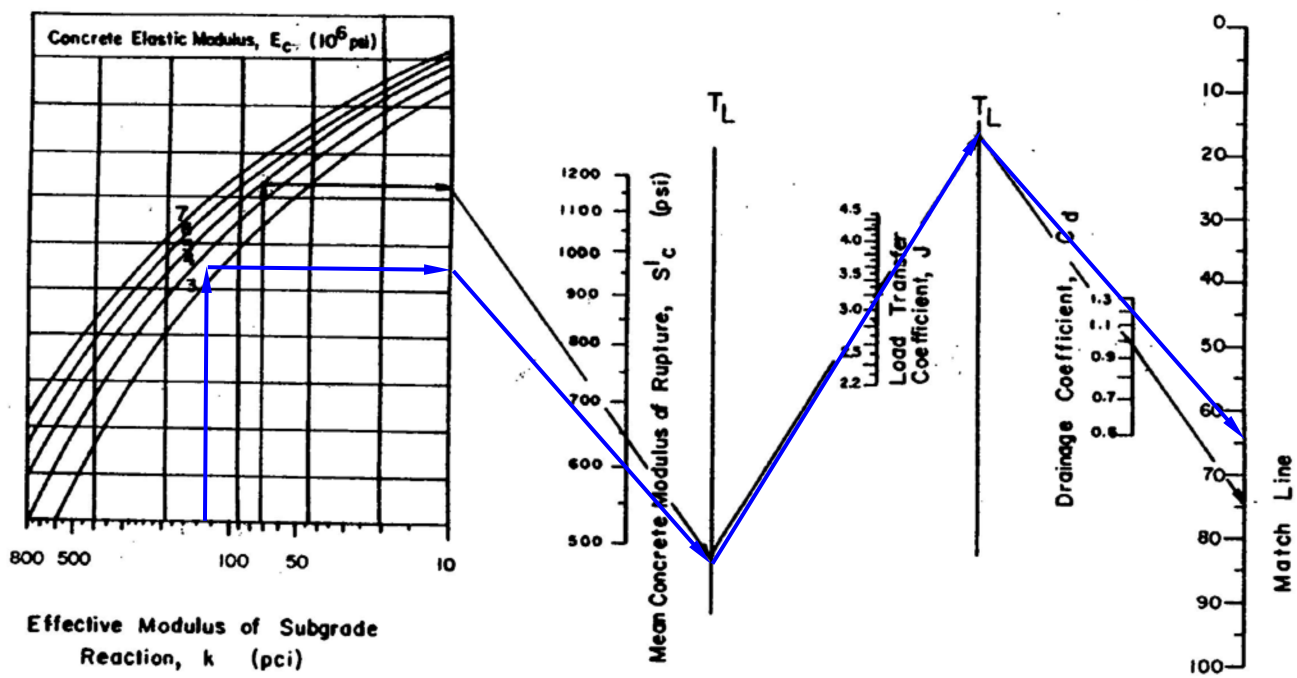
P-4 (A Picture of Grouting using Tremie Method)

APPENDIX C

Pavement Design Computations for Thoroughfare Traffic

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R * S_o + 7.35*\log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+\frac{1.624*10^7}{(D+1)^{8.46}}} + (4.22-0.32p_t)*\log_{10}\left[\frac{S_c' * C_d\left[D^{0.75}-1.132\right]}{215.63*J\left[D^{0.75}-\frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$



Legend :

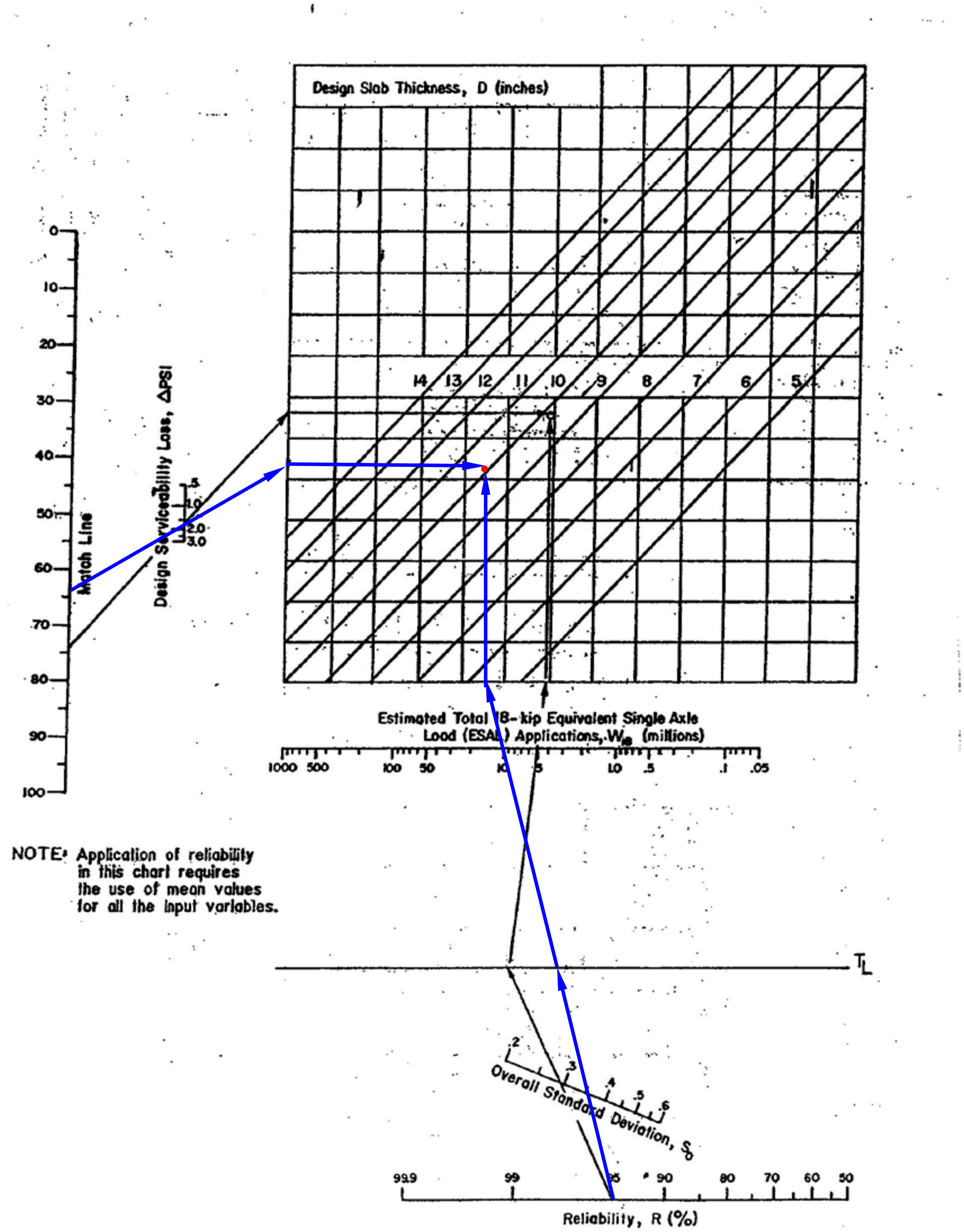
Pavement Design for This Study

Calculation:

k = 130 pci	S_0 = 0.35
$E_c = 3.60\times 10^6$	R = 95%
S_c = 600 psi	ΔPSI = 4.5-2.5 = 2.0
J = 3.2	
C_d = 1.2	

Solution:

W_{18} (18kip ESAL x 10^6)	Concrete Pavement Thickness, inch(es)
10.0	10.0



NOTE: Application of reliability in this chart requires the use of mean values for all the input variables.

DESIGN CHART FOR RIGID PAVEMENTS BASED ON USING MEAN VALUES FOR EACH INPUT VARIABLES (SEGMENT 2)

APPENDIX D

OSHA Soil Classification

OSHA SOIL CLASSIFICATION

General

Occupational Safety and Health Administration (OSHA) has required a trench protective system for trenches deeper than five-ft. Trenches that are deeper than five-ft, should be shored, sheeted, braced or laid back to a stable slope, or some other appropriate means of protection should be provided where workers might be exposed to moving ground or caving. OSHA developed a soil classification system to be used as a guideline in determining protective requirements for trench excavations.

OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. These classifications are summarized in the following report sections.

Stable Rock

means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A Soil

means cohesive soils with an unconfined compressive strength of 1.5-ton per square foot (tsf) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam, silty clay loam, sandy clay loam, caliche and hardpan. No soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving or similar effects; or

The soil has been previously disturbed; or

- The soil is part of a slope, layered system where the layers dip into the excavation on a slope of 4(h): 1(v) or greater; or
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soil

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; or
- Granular cohesionless soils including: angular gravel, silt, silt loam, sandy loam, and in some case, silty clay loam and sandy clay loam; or
- Previously disturbed soils except those which would otherwise be classified as Type C soil; or
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

- Dry rock that is not stable; or
- Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than 4(h): 1(v), but only if the material would otherwise be classified as Type B.

Type C Soil

- Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
- Granular soils including gravel, sand, and loamy sand; or
- Submerged soil or soil from which water is freely seeping; or
- Submerged rock that is not stable; or
- Materials in a sloped, layered system where the layers dip into the excavation on a slope 4 (h) : 1(v) or steeper.

Under the assumption that appropriate groundwater control measures are carried out, and the groundwater table, if present, is lowered and maintained at least 3 feet below the excavation depths, the stable cohesive soils (CL) & (CH), with unconfined compressive strength greater than 0.5 tsf, are classified as OSHA soil Type "B". The granular soils, which are less stable, are classified as OSHA soil Type "C".

Based on our geotechnical exploration and laboratory test results details of soil classifications at each boring are summarized below:

OSHA SOIL TYPE

Boring No.	Depth Range [1], ft	Soil Type	OSHA Soil Classification
B-1	0.5 – 2	Fill: Fat Clay (CH)	B
	2 – 21	Fat Clay (CH)	B
B-2	0.75 – 2	Fill: Fat Clay (CH)	B
	2 – 8	Fat Clay (CH)	C
	8 – 10	Fat Clay (CH)	B
	10 – 12	Fat Clay (CH)	C
	12 – 14	Fat Clay (CH)	B
	14 – 24	Sandy Silt (ML)	C

Boring No.	Depth Range [1], ft	Soil Type	OSHA Soil Classification
B-3	0.7 – 2	Fill: Fat Clay (CH)	C
	2 – 8	Fat Clay (CH)	B
	8 – 10	Fat Clay (CH)	C
	10 – 12	Lean Clay with Sand (CL)	B
	12– 18	Lean Clay with Sand (CL)	C
	18 – 26	Silty Sand (SM)	C
B-4	0.6 – 6	Fill: Fat Clay (CH)	B
	6 – 33	Fat Clay (CH)	B
B-5	0.6 – 2	Fill: Fat Clay (CH)	C
	2 – 8	Fill: Fat Clay (CH)	B
	8 – 10	Fat Clay (CH)	C
	10 – 12	Fat Clay (CH)	B
	12 – 20	Sandy Silt (ML)	C
B-6	0.7 – 2	Fill: Fat Clay (CH)	C
	2 – 6	Fat Clay (CH)	C
	6 – 8	Fat Clay (CH)	B
	8 – 10	Fat Clay (CH)	C
	10 – 25	Fat Clay (CH)	B
B-7	0.6 – 2	Fill: Fat Clay (CH)	C
	2 – 16	Fat Clay (CH)	B
	16 – 18	Fat Clay (CH)	C
	18 – 25	Fat Clay (CH)	B

Note: 1. Refer to each boring log for soils stratigraphy